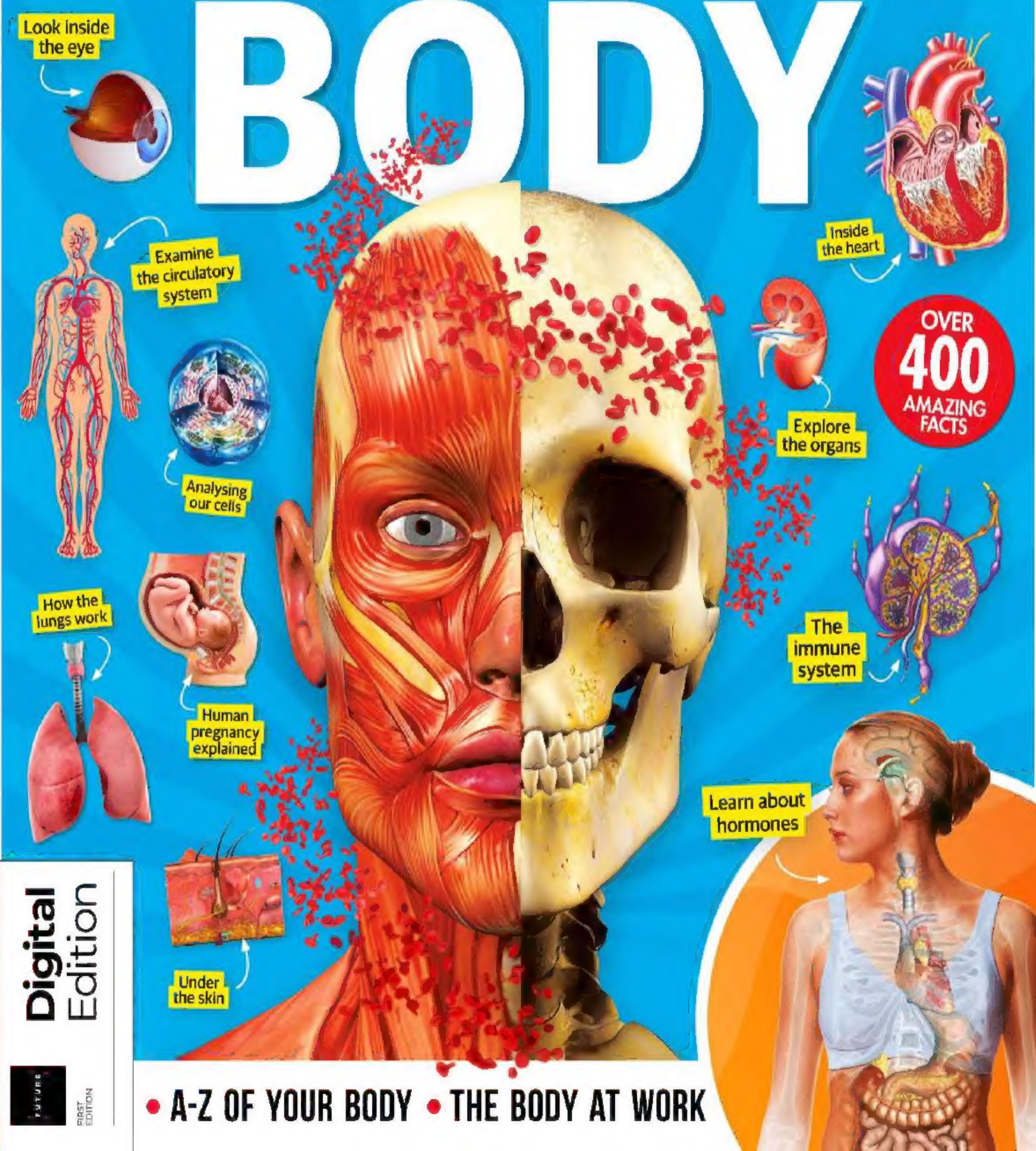
NEW

EVERYTHING YOU NEED TO KNOW ABOUT THE HUMAN BODY



OVER 400 AMAZING FACTS

Digital Edition

FUTURE

FIRST EDITION

• A-Z OF YOUR BODY • THE BODY AT WORK

WELCOME

Humans are naturally curious creatures. It is, therefore, hardly a surprise that we all have questions about the human body that we want to know the answers to. How do our organs function? How do our wounds heal? Why do we dream? We answer these burning questions and more in Everything You Need to Know About the Human Body. Join us as we take you on a journey through the human anatomy, from your skull all the way down to your toes, with anatomical illustrations and detailed explanations to help you understand the wonder that is our bodies.

FUTURE

THE EVERYTHING YOU NEED TO KNOW ABOUT

THE HUMAN BODY

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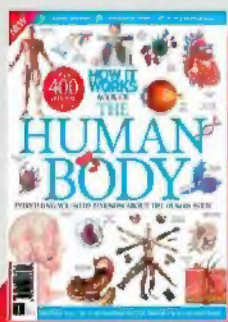

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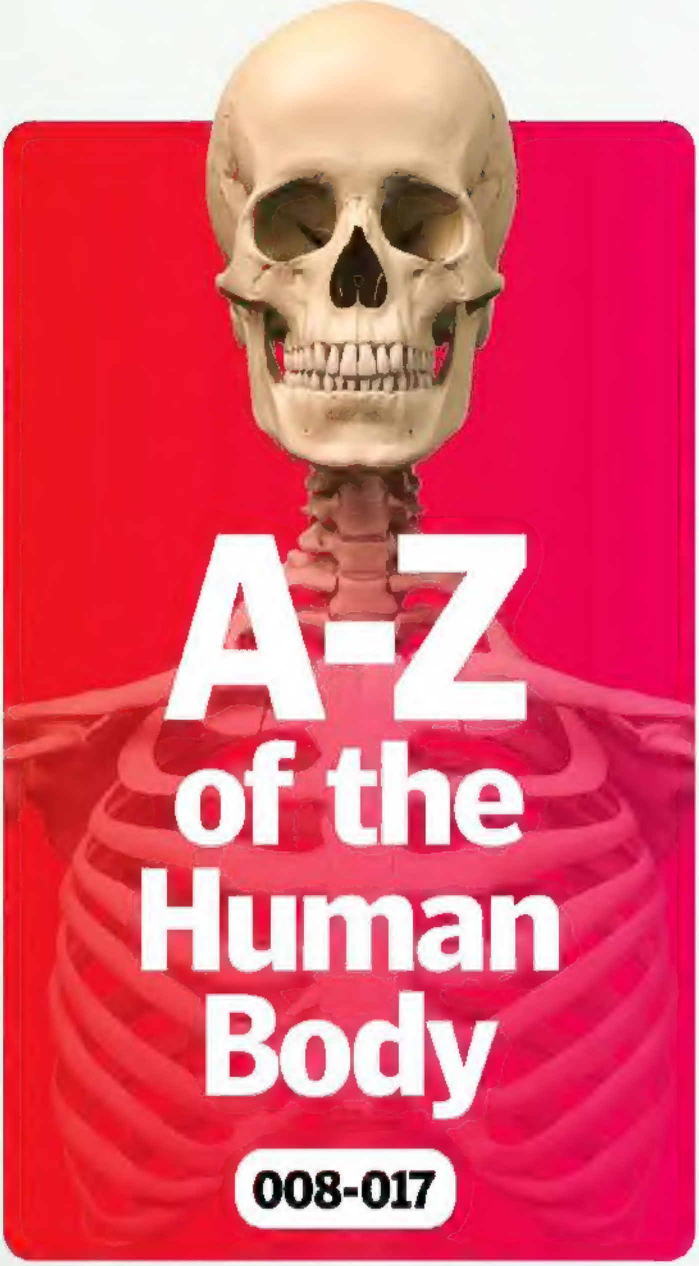

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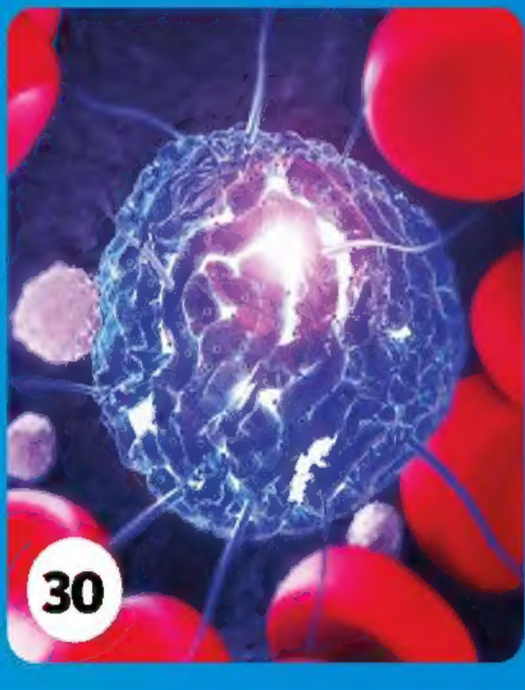

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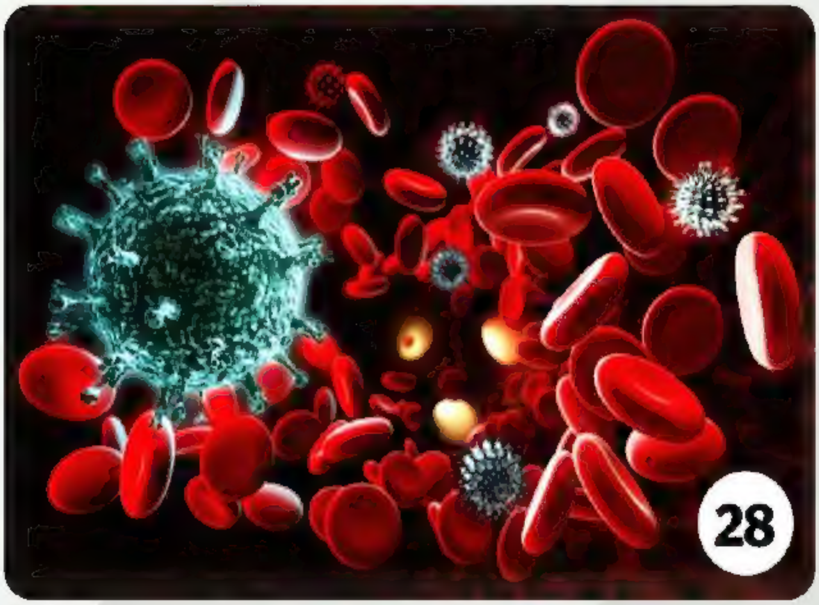

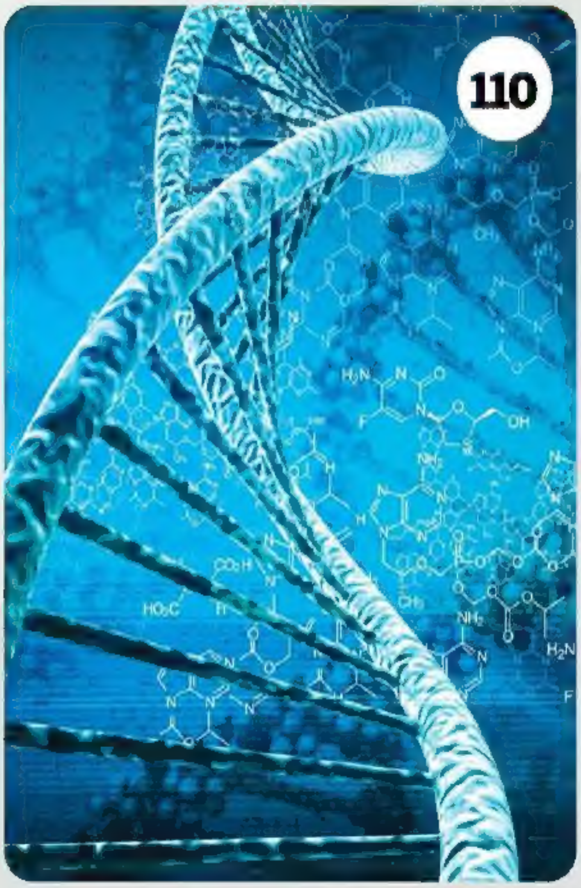

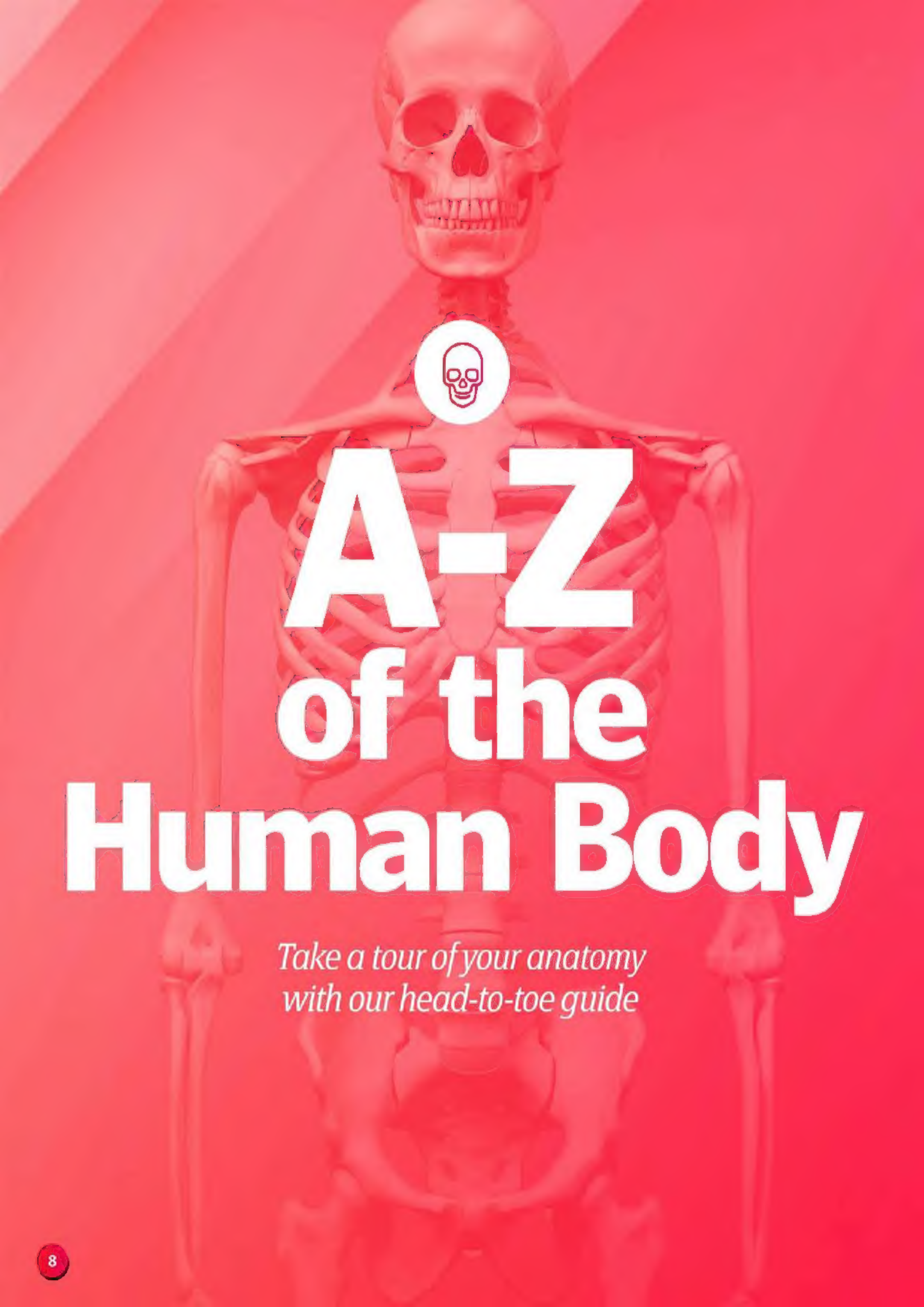

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Take a tour of your anatomy with our head-to-toe guide


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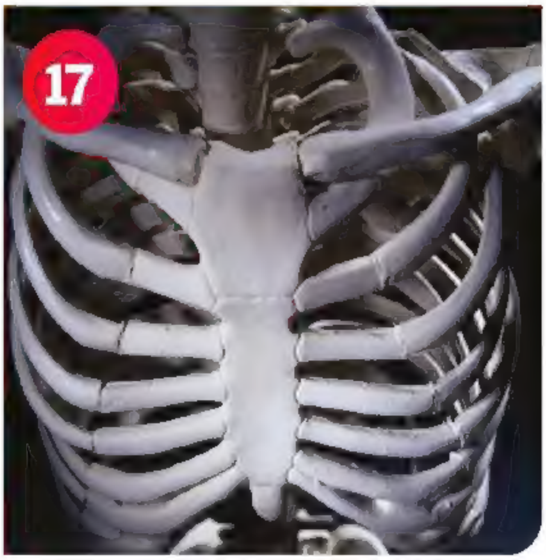
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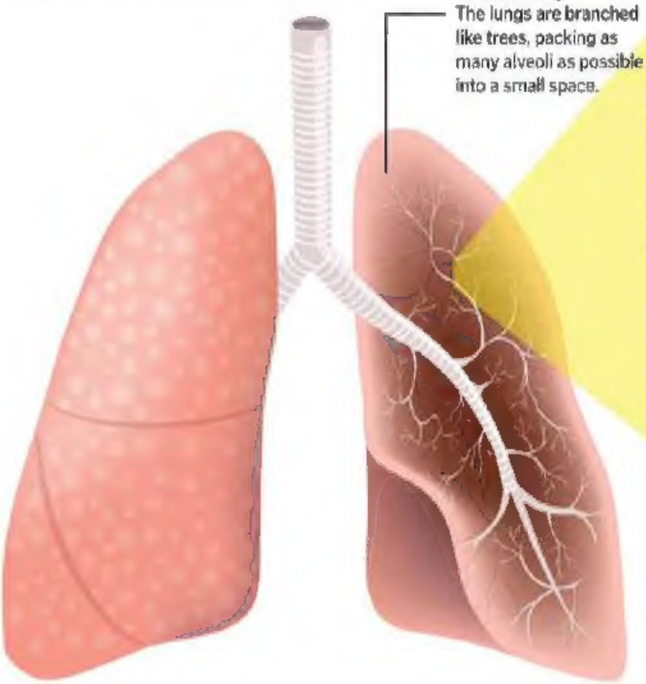
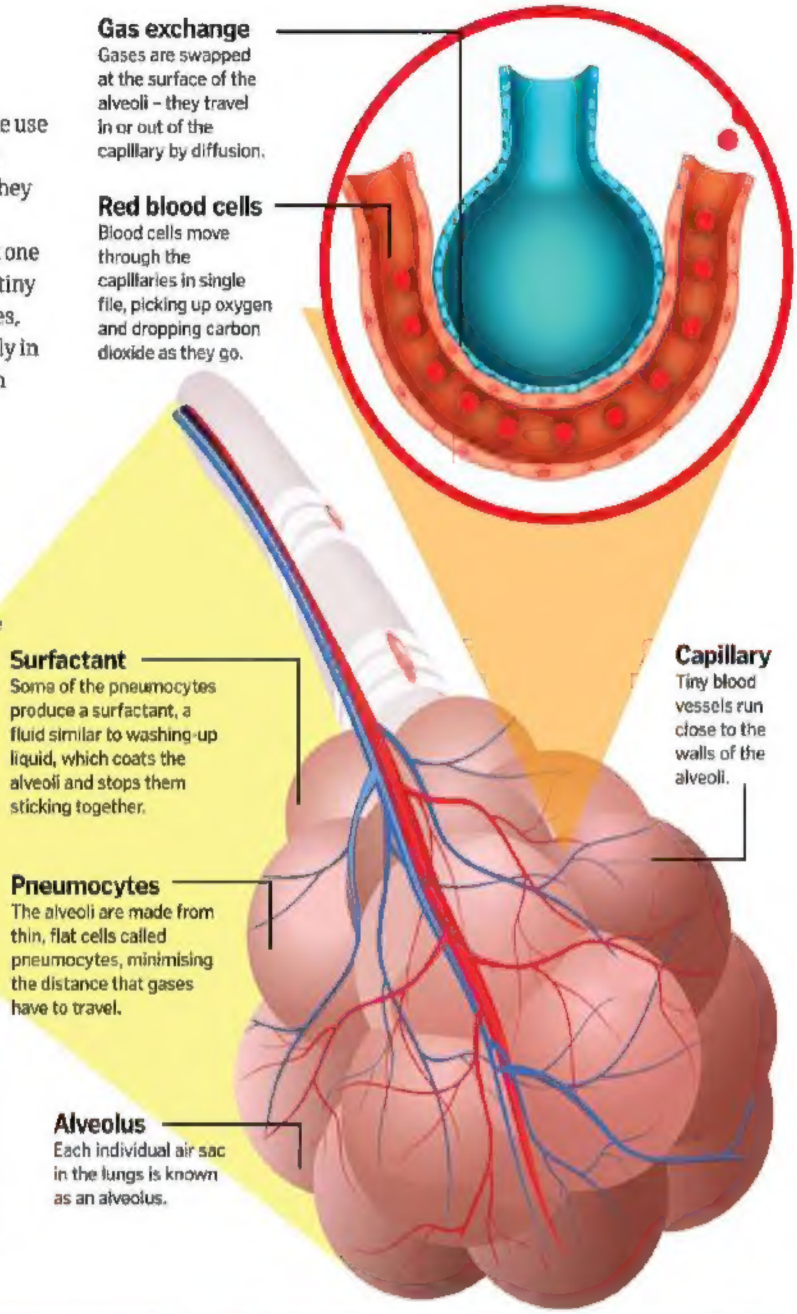
Alveoli

a As an adult, your lungs have a total surface area of around 50 square metres. That's around a quarter of the size of a tennis court! Packing all of that into your chest is no mean feat, and the body does it using structures called alveoli. They look a little bit like bunches of grapes, packed tightly inside the lungs in order to maximise the use of the available volume in the chest. When you breathe in, they expand, filling with air. The surfaces of the alveoli are just one cell thick and surrounded by tiny blood vessels called capillaries, allowing gases to diffuse easily in and out of the blood with each breath you take.

Understanding alveoli

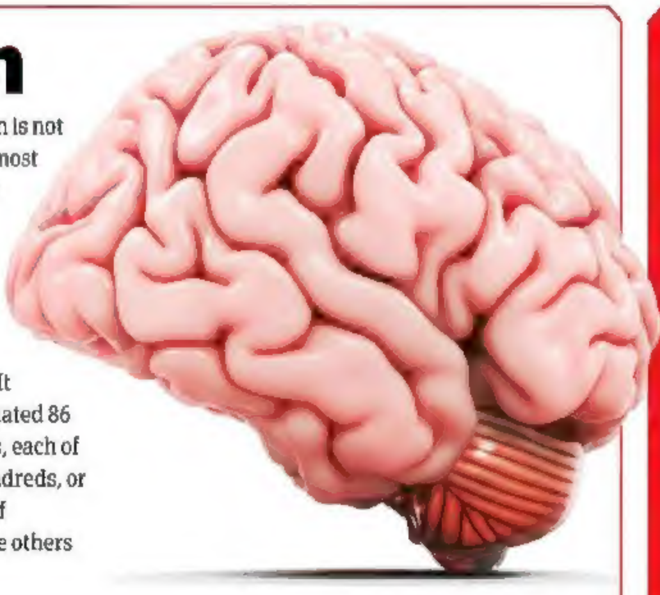
How does your body pack such a huge surface area inside your chest?





Brain

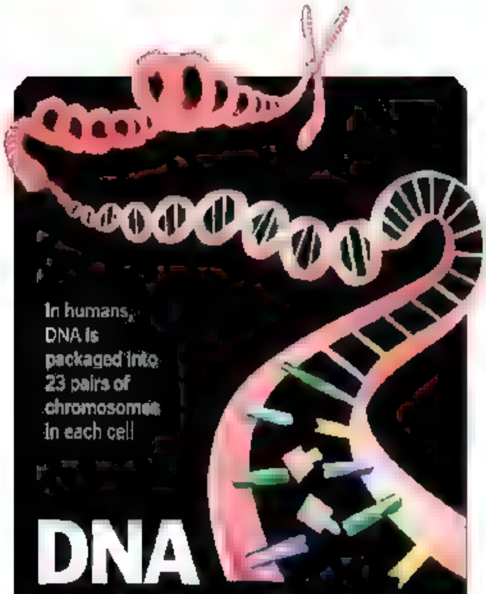
b The brain is not just the most complex structure in the human body, but it is also the most complex object in the known universe. It contains an estimated 86 billion nerve cells, each of which makes hundreds, or even thousands of connections to the others around it.



Cornea

c The cornea is the protective coating that keeps your eye free of dust and debris. It looks clear but is actually made up of several layers of cells. Light bends slightly as it passes through the cornea, helping to focus incoming rays on the back of your eye.

It is, in fact, possible to donate corneas for transplant, helping to restore vision to people with corneal damage.



In humans, DNA is packaged into 23 pairs of chromosomes in each cell

DNA

d Perhaps the most important single structure inside your body is your DNA. Present in almost every cell (red blood cells get rid of theirs), it carries the genetic recipes needed to build, grow, repair and maintain you. These recipes are written in combinations of four-letter code (ACTG), and in humans are 3 billion letters long.

Fat

f You have two main types of fat: brown and white. Brown fat burns calories to keep you warm, while white fat stores energy and produces hormones. Children have more brown fat than adults, and it's mainly found in the neck and shoulders, around the organs, and along the spinal cord.

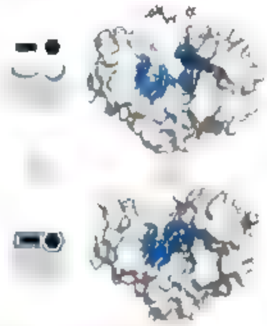
This scan shows the distribution of brown fat around the head, shoulders, heart and spine

Enzymes

e Enzymes are often called 'biological catalysts', and their job is to speed up chemical reactions. You are full of dissolved chemicals with the potential to come together or break apart to form the biological building blocks that you need to stay alive, but the reactions happen too slowly on their own.

Enzymes are molecules with 'active sites' that lock on to other molecules, bringing them close together so that they can react, or bending their structures so that they can combine or break apart more easily. The enzymes themselves do not actually get involved in the reactions; they just help them to happen faster.

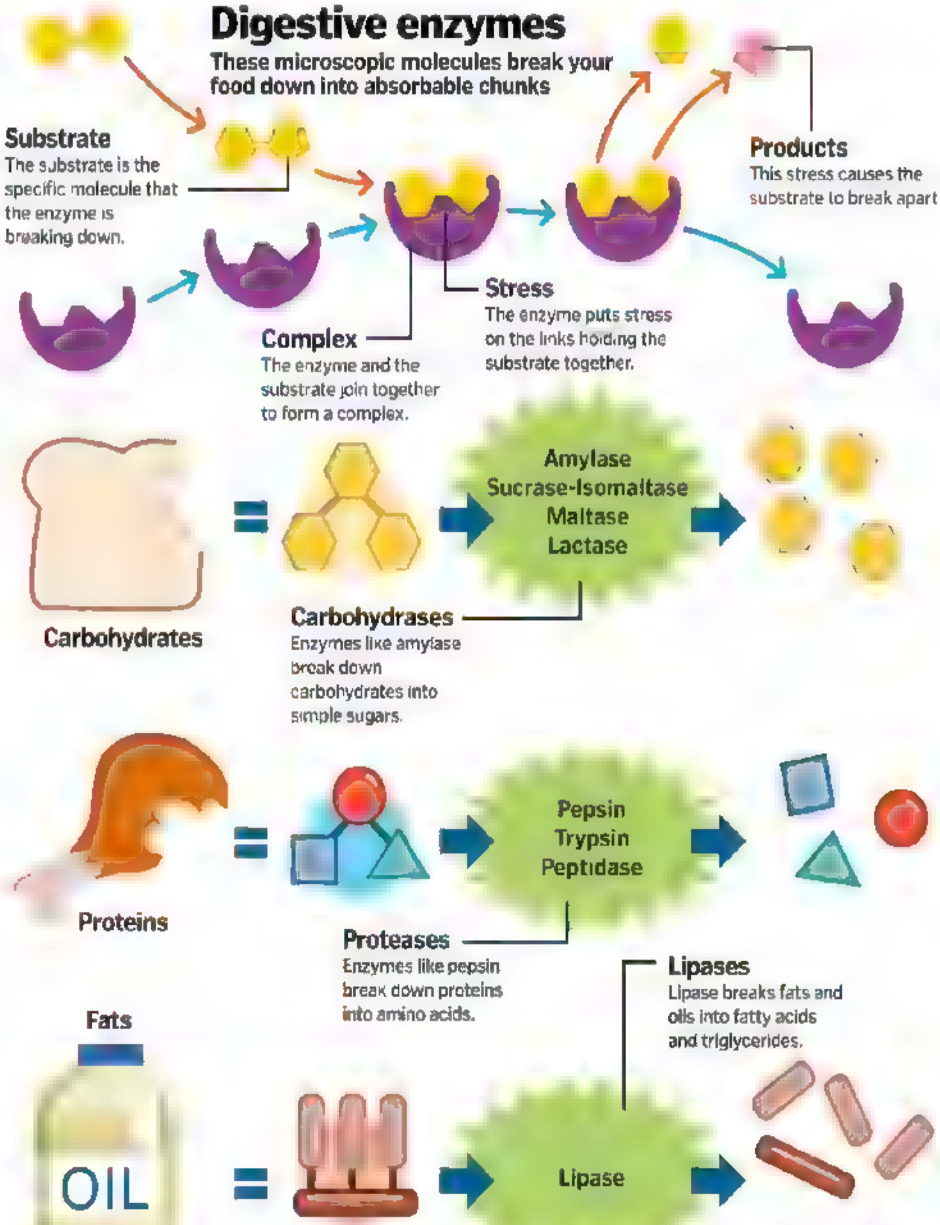
Some of the most well-known enzymes are the ones in your digestive system. These are important for breaking down the molecules in your food. However, these aren't the only enzymes in your body. There are others responsible for building molecules, snipping molecules, tidying up when molecules are no longer needed, and even destroying invading pathogens.



This enzyme brings two molecules close together so that they can react

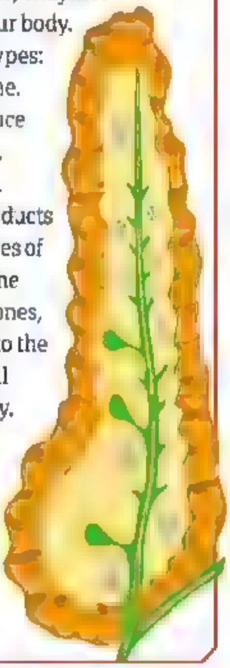
Digestive enzymes

These microscopic molecules break your food down into absorbable chunks

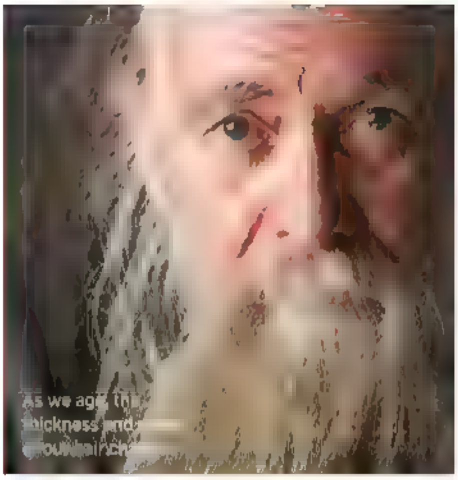


Glands

g These structures are responsible for producing and releasing fluids, enzymes and hormones into your body. There are two major types: endocrine and exocrine. Exocrine glands produce substances like sweat, saliva and mucus, and release these through ducts onto the skin or surfaces of other organs. Endocrine glands produce hormones, which are released into the blood to send chemical signals across the body.



The pancreas has both endocrine glands (blue clusters) and exocrine glands (green branches)



Hair

h You have around 5 million hair follicles and, surprisingly, only around 100,000 of those are on your scalp. The others are spread across your body – on your skin, lining your eyelids, and inside your nose and ears. Hair has many functions, helping to keep you warm, trapping dirt and debris, and even (in the case of eyebrows) diverting sweat and rainwater away from your eyes

Intestines

i After exiting your stomach, food enters your intestines and begins a 7.5-metre journey out of your body. The small intestine comes first, and is filled with digestive enzymes that get to work breaking down and absorbing the molecules from your meal. After this, the large intestine absorbs as much water as possible before the waste is passed out.

Joints

j

Types of joints

Each type of joint in your body allows for a different range of movement

"There are more than 200 bones in the human body"

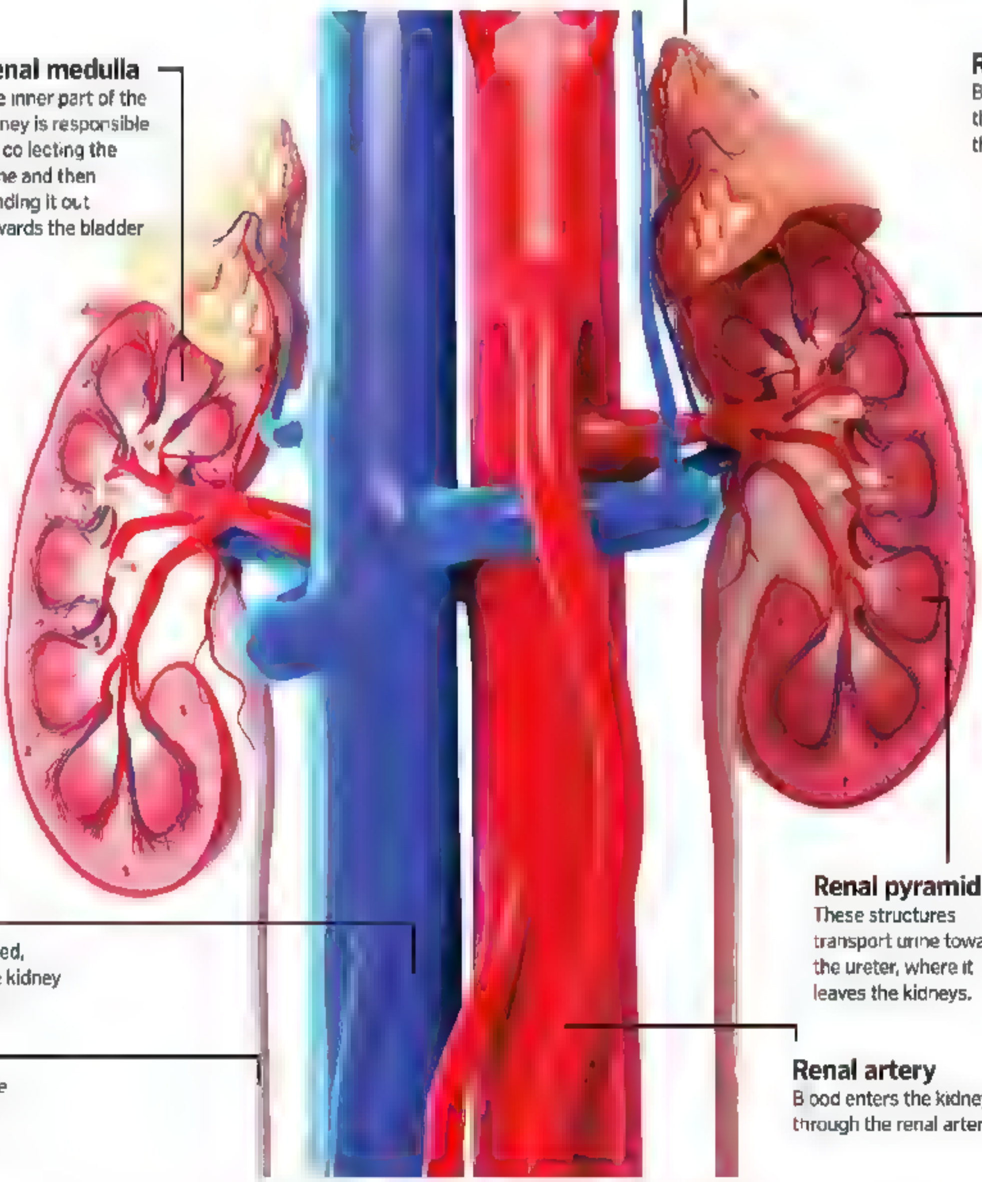
Kidneys

"Your kidneys keep your blood clean and your body hydrated"

K Your kidneys keep your blood clean and your body properly hydrated. Blood passes in through knots of blood vessels that are wider on the way in and narrower on the way out. This creates an area of high pressure that forces water and waste out through gaps in the vessel walls. Blood cells and proteins remain in the bloodstream. Each kidney has around a million of these miniature filtering systems, called nephrons, cleaning the blood every time it passes through. The fluid then tracks through bendy tubes (known as convoluted tubules), where important minerals are collected and returned to the blood. Excess water and waste products are sent on to the bladder as urine to be excreted. Depending on how much salt and water are in your body, your kidneys adjust the amount of fluid that they get rid of, helping to keep your hydration levels stable.

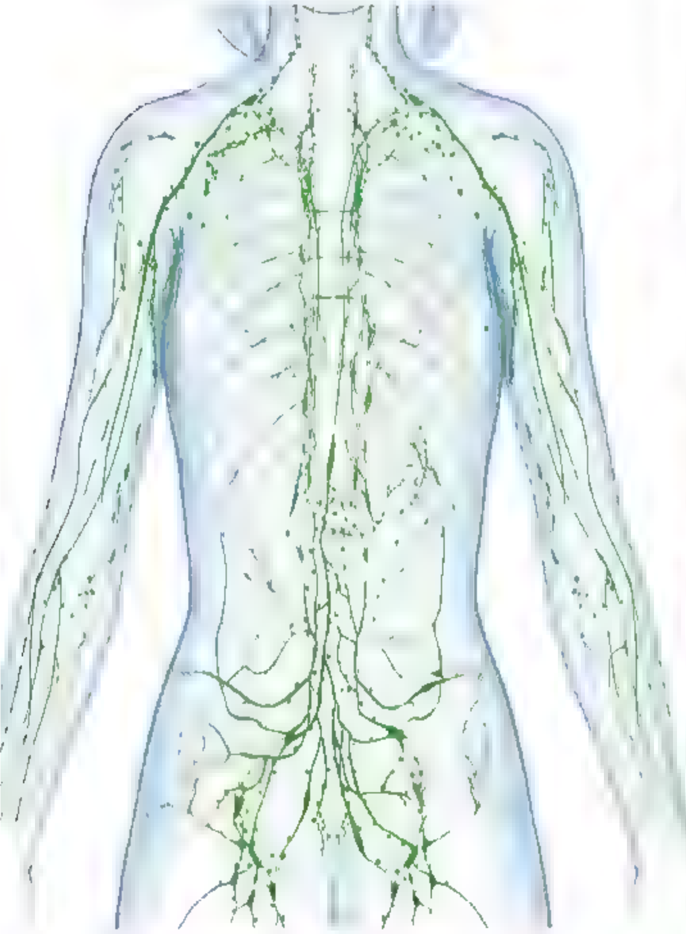
The kidneys

These simple-looking organs are packed with microscopic filtration machinery



Lymphatic system

l Everyone knows about the circulatory system that transports blood around the body, but there is a second network of tubes and vessels that is often forgotten. The lymphatic system collects fluid from the tissues, and returns it to the blood via veins in the chest. It is also used by the immune system to monitor and fight infection.



The lymphatic system is studded with lymph nodes, used as outposts by the immune system

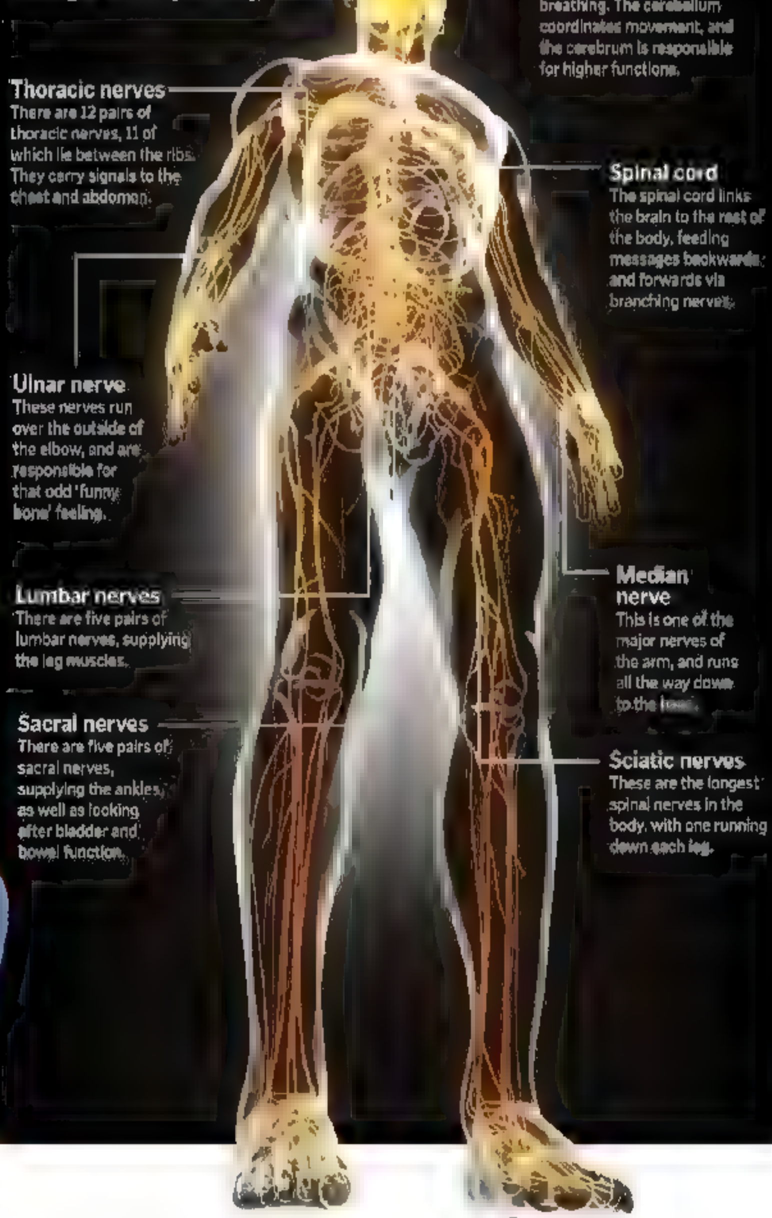
Nervous system

n This is your body's electrical wiring, transmitting signals from your head to your toes, and everywhere in between. The nervous system can be split into two main parts: central and peripheral. The central nervous system is the brain and spinal cord, and makes up the control centre of your body. While the brain is in charge of the vast majority of signals, the spinal cord can take care of some things on its own. These are known as 'spinal reflexes', and include responses like the knee-jerk reaction. They bypass the brain, which allows them to happen at super speed.

The peripheral nervous system is the network of nerves that feed the rest of your body, and it can be divided into two parts: somatic and autonomic. The somatic nervous system looks after everything that you consciously feel and move, like clenching your leg muscles and sensing pain if you step on a nail. The autonomic system takes care of the things that go on in the background, like keeping your heart beating and your stomach churning.

Your nerve network

The nervous system sends electrical messages all over your body



Mitochondria

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Oesophagus

O Sometimes known as the 'food pipe', this stretchy muscular tube links your mouth to your stomach. When you swallow, circular muscles contract to push food into your digestive tract, starting at the top and moving down in waves.

"The peripheral nervous system is the network of nerves that feed the rest of your body"

Pancreas

P This leaf-shaped organ plays two vital roles in digestion. It produces enzymes that break down food in the small intestine, and it makes the hormones insulin and glucagon, which regulate the levels of sugar in the blood.

Quadriceps

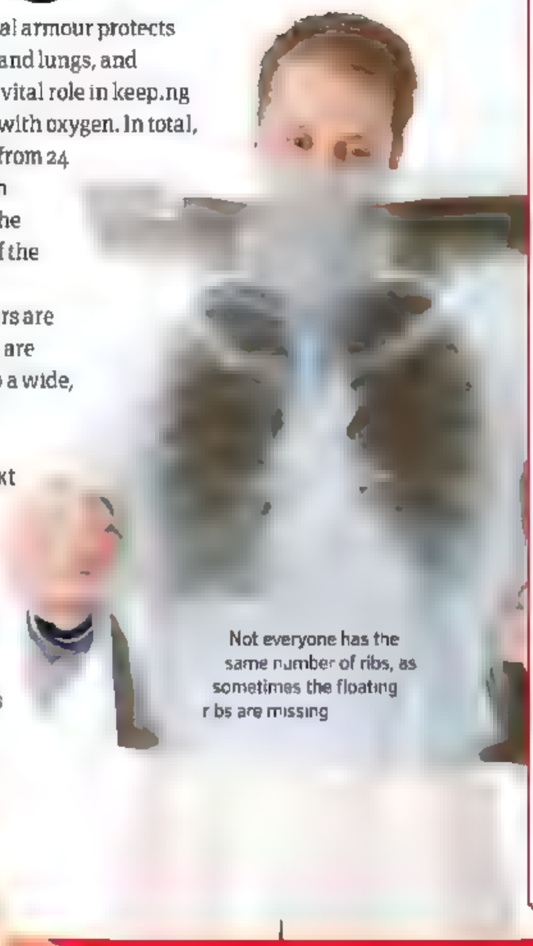
Q There aren't many body parts that begin with the letter Q, but this bundle of four muscles in the upper leg is an important one. The quadriceps femoris connect the pelvis and thigh to the knee and shinbone, and are used to straighten the leg.

© Thinkstock

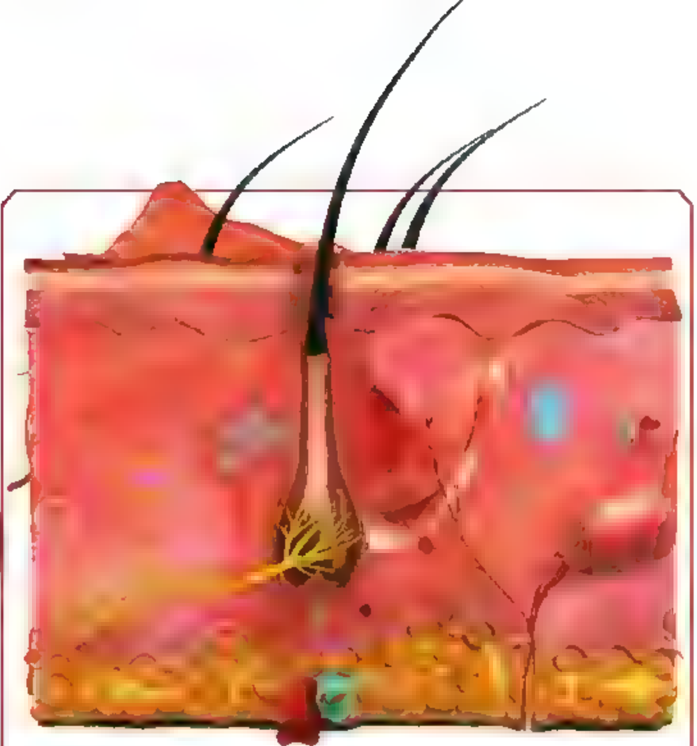
Ribcage

This internal armour protects your heart and lungs, and performs a vital role in keeping your body supplied with oxygen. In total, the ribcage is made from 24 curved bones, which connect in pairs to the thoracic vertebrae of the spine at the back.

Seven of these pairs are called true ribs, and are linked at the front to a wide, flat bone called the sternum (or breastbone). The next three pairs, known as false ribs, connect to the sternum indirectly, and the final two don't link up at all, and are known as as floating ribs.



Not everyone has the same number of ribs, as sometimes the floating ribs are missing



Skin

Your skin is the largest organ in your body. It is made up of three distinct layers: the epidermis on the outside, the dermis beneath, and the hypodermis right at the bottom.

The epidermis is waterproof, and is made up of overlapping layers of flattened cells. These are constantly being replaced by a layer of stem cells that sit just beneath. The epidermis also contains melanocytes, which produce the colour pigment melanin.

The dermis contains hair follicles, glands, nerves and blood vessels. It nourishes the top layer of skin, and produces sweat and sebum. Under this is a layer of supporting tissue called the hypodermis, which contains storage space for fat.

Tongue

Umbilical cord

This spongy structure is packed with blood vessels, and connects a developing baby to its placenta. The placenta attaches to the wall of the mother's uterus, tapping into her blood supply to extract oxygen and nutrients. After birth, the cord dries up and falls away, leaving a scar called the belly button.

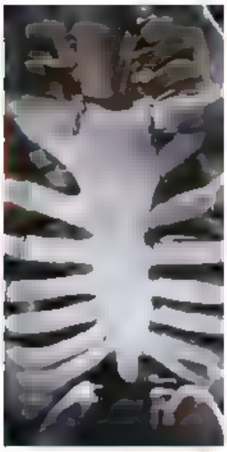
The umbilical cord is usually cut at birth, separating the baby from the placenta

Vocal cords

V The vocal cords are folds of membrane found in the larynx, or voice box. They can be used to change the flow of air out of the lungs, allowing us to speak and sing. As air passes through the gap between the folds, they vibrate, producing sound.

When the vocal cords are closed, pressure builds and they vibrate

Xiphoid process



X This is the technical term used for the little lump that can be found at the bottom of your sternum, or breastbone. Medical professionals use the xiphoid process as a landmark in order to find the right place for chest compressions during CPR.

White blood cells

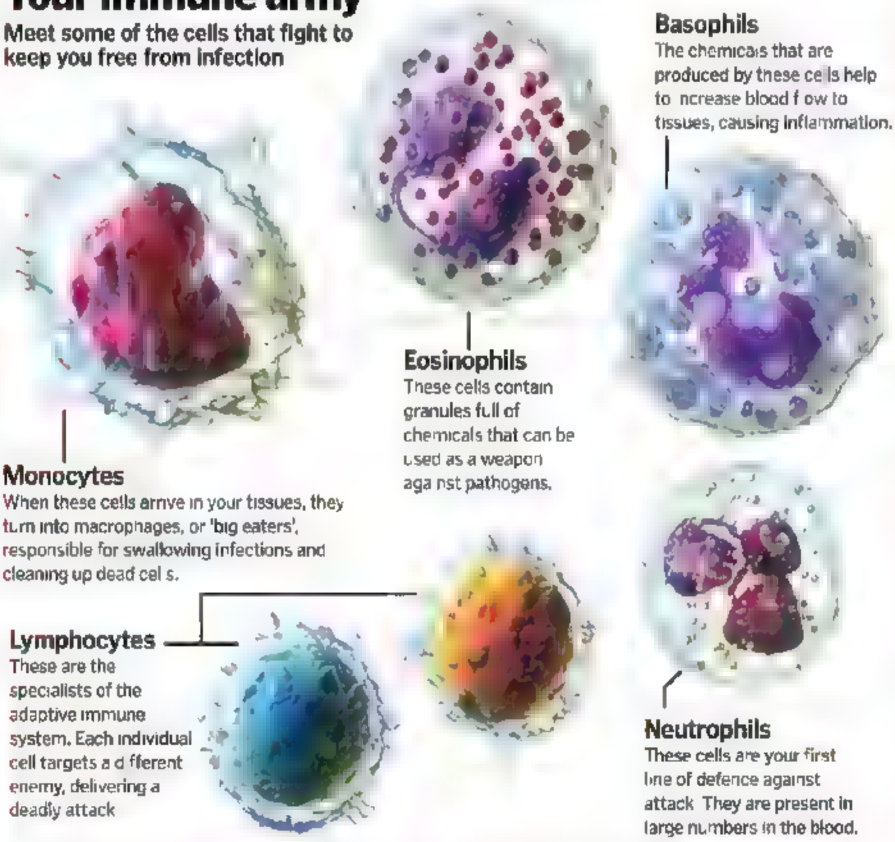
W These specialist cells make up your own personal army, tasked with defending your body from attack and disease. There are several different types, each with a unique role to play in keeping your body free of infection.

The first line of defence is called the innate immune system. These cells are the first ones on the scene, and they work to contain infections by swallowing and digesting bacteria, as well as killing cells that have been infected with viruses.

If the innate immune system can't keep the infection at bay, then they call in the second layer of defence – the adaptive immune system. These cells mount a stronger and more specific attack, and can even remember which pathogens they've fought before.

Your immune army

Meet some of the cells that fight to keep you free from infection



Basophils
The chemicals that are produced by these cells help to increase blood flow to tissues, causing inflammation.

Eosinophils
These cells contain granules full of chemicals that can be used as a weapon against pathogens.

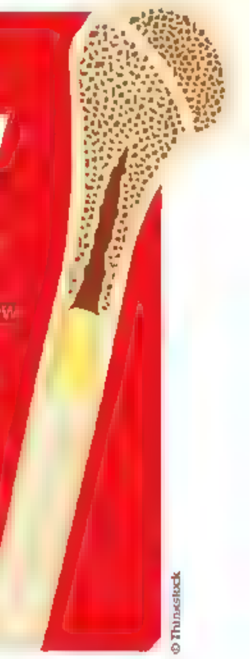
Monocytes
When these cells arrive in your tissues, they turn into macrophages, or 'big eaters', responsible for swallowing infections and cleaning up dead cells.

Lymphocytes
These are the specialists of the adaptive immune system. Each individual cell targets a different enemy, delivering a deadly attack

Neutrophils
These cells are your first line of defence against attack. They are present in large numbers in the blood.

Yellow marrow

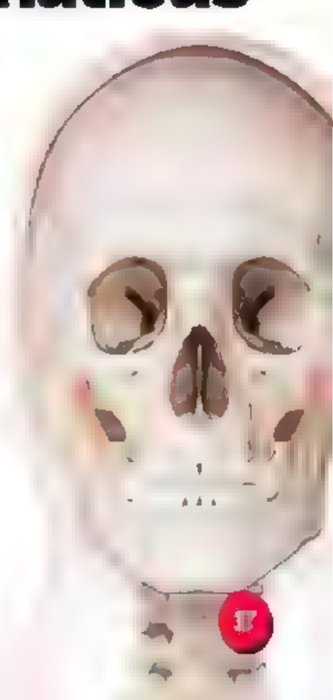
Y There are two main types of bone marrow: yellow and red. Red marrow is responsible for producing new blood cells, while yellow marrow contains mainly fat. Red marrow gradually changes into yellow marrow as you get older.



Yellow marrow mainly found in the long bones of the arms and legs

Zygomaticus major

Z This is one of the key muscles responsible for your smile, joining the corner of the mouth to the cheekbone, and pulling your lips up and out. Depending on your anatomy, it is also the muscle responsible for cheek dimples.



Human Anatomy

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the essentials of the human body

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50 Amazing facts about the human body

There are lots of medical questions everybody wants to ask but we just never get the chance... until now!

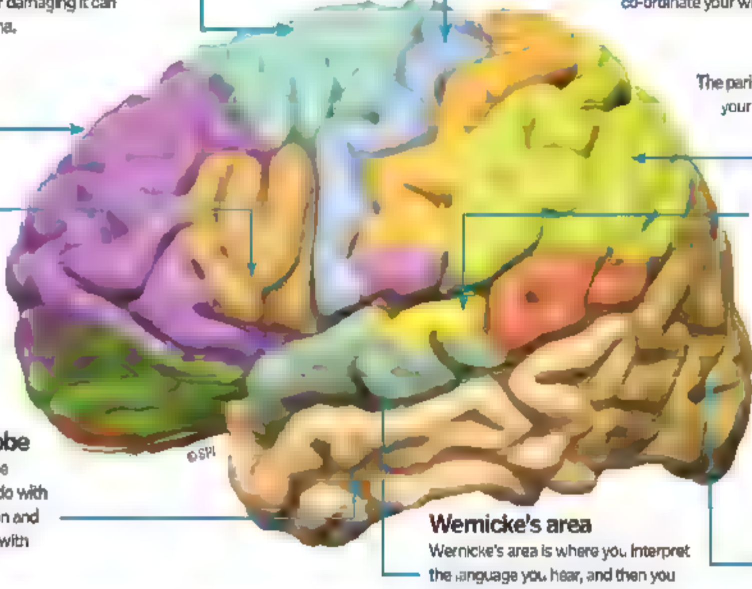
The human body is the most complex organism we know and if humans tried to build one artificially, we'd fail abysmally. There's more we don't know about the body than we do know. This includes many of the quirks and seemingly useless traits that our species carry. However, not all of these traits are as bizarre as they may seem, and many have an evolutionary tale behind them.

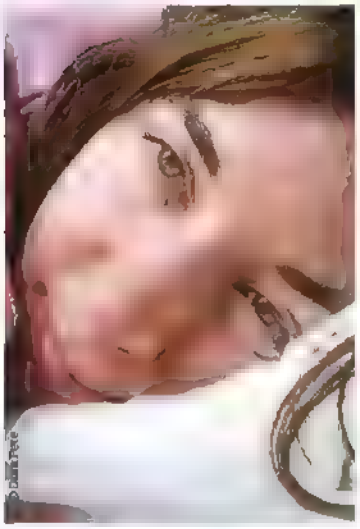
Asking these questions is only natural but most of us are too embarrassed or never get the opportunity – so here's a chance to clear up all those niggling queries. We'll take a head-to-toe tour of the quirks of human biology, looking at everything from tongue rolling and why we are ticklish through to pulled muscles and why we dream.

1 How do we think?

What are thoughts? This question will keep scientists, doctors and philosophers busy for decades to come. It all depends how you want to define the term 'thoughts'. Scientists may talk about synapse formation, pattern recognition and cerebral activation in response to a stimulus (seeing an apple and recognising it). Philosophers, and also many scientists, will argue that a network of neurons cannot possibly explain the many thousands of thoughts and emotions that we must deal with. A sports doctor might state that when you choose to run, you activate a series of well-trodden pathways that lead from your brain to your muscles in less than just a second.

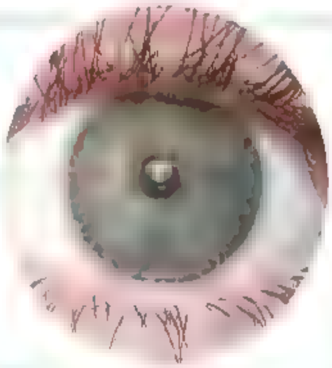
There are some specifics we do know though – such as which areas of your brain are responsible for various types of thoughts and decisions.





2 In the mornings, do we wake up or open our eyes first?

Sleep is a gift from nature, which is more complex than you think. There are five stages of sleep which represent the increasing depths of sleep – when you're suddenly wide awake and your eyes spring open, it's often a natural awakening and you're coming out of rapid eye movement (REM) sleep; you may well remember your dreams. If you're coming out of a different phase, e.g. when your alarm clock goes off, it will take longer and you might not want to open your eyes straight away!



3 Do eyeballs grow like the rest of the body?

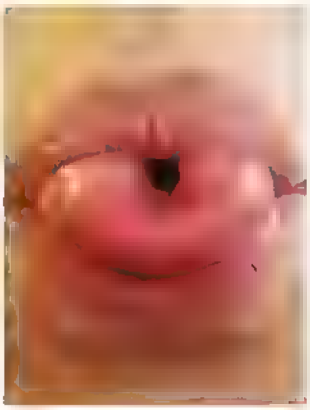
Only a small amount – this is actually why babies appear to be so beautiful, as their eyes are out of proportion and so appear bigger.

4 Why do we fiddle subconsciously? I'm constantly playing with my hair

This is a behavioural response – some people play with their hair when they're nervous or bored. For the vast majority of people such traits are perfectly normal. If they begin to interfere with your life, behavioural psychologists can help – but it's extremely rare that you'll end up there.

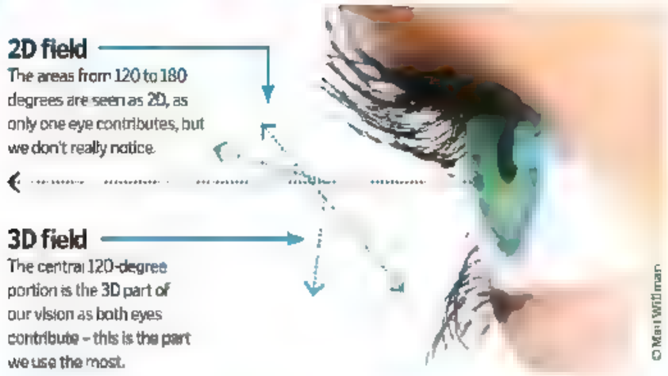
5 Why can some people roll their tongues but others can't?

Although we're often taught in school that tongue rolling is due to genes, the truth is likely to be more complex. There is likely to be an overlap of genetic factors and environmental influence. Studies on families and twins have shown that it simply cannot be a case of just genetic inheritance. Ask around – the fact that some people can learn to do it suggests that in at least some people, it's environmental (i.e. a learned behaviour) rather than genetic (inborn).



6 What is a pulse?

When you feel your own pulse, you're actually feeling the direct transmission of your heartbeat down your artery. You can only feel a pulse where you can compress an artery against a bone, e.g. the radial artery at the wrist. The carotid artery can be felt against the vertebral body, but beware, press too hard and you can actually faint. Press both at the same time and you'll cut off the blood to your brain and, as a protective mechanism, you'll definitely faint!

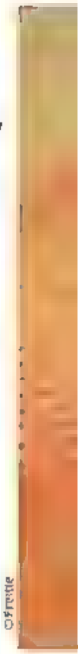


7 What's my field of vision in degrees?

The human field of vision is just about 180 degrees. The central portion of this (approximately 120 degrees) is binocular or stereoscopic – i.e. both eyes contribute, allowing depth perception so that we can see in 3D. The peripheral edges are monocular, meaning that there is no overlap from the other eye, so we see in 2D.

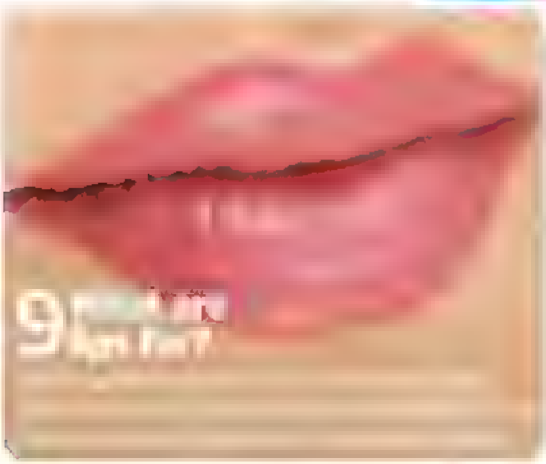
12 Why do we burp?

A burp is the body's way of releasing gas naturally from your stomach. This gas has either been swallowed or is the result of something that you have ingested – such as a sparkling drink. The sound is vibrations, which are taking place in the oesophageal sphincter, the narrowest part of the gastrointestinal tract.



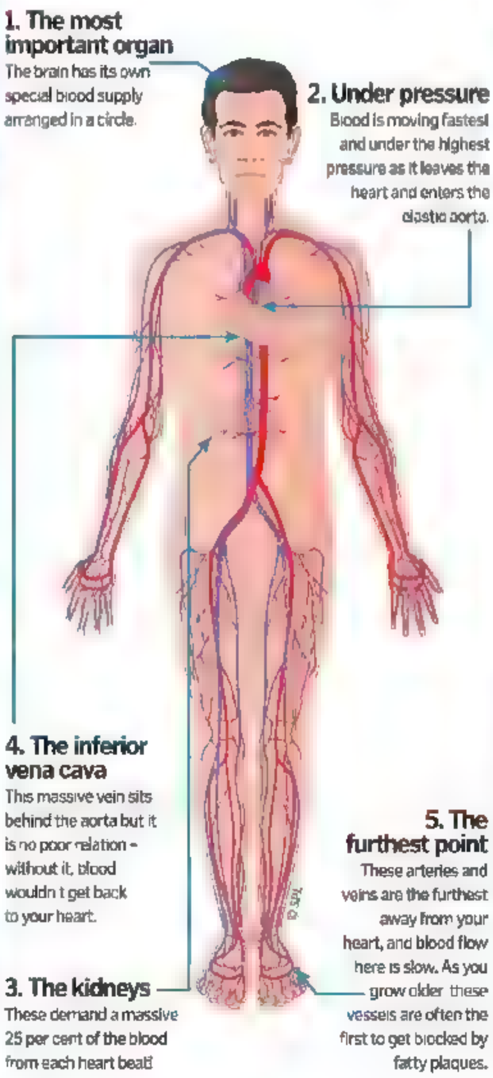
8 What is the point of tonsils?

The tonsils are collections of lymphatic tissues that are thought to help fight off pathogens from the upper respiratory tract. However, the tonsils can sometimes become infected – leading to tonsillitis. The ones you can see at the back of your throat are just part of the ring of tonsils. You won't miss them if they're taken out for recurrent infections, as the rest of your immune system will compensate.



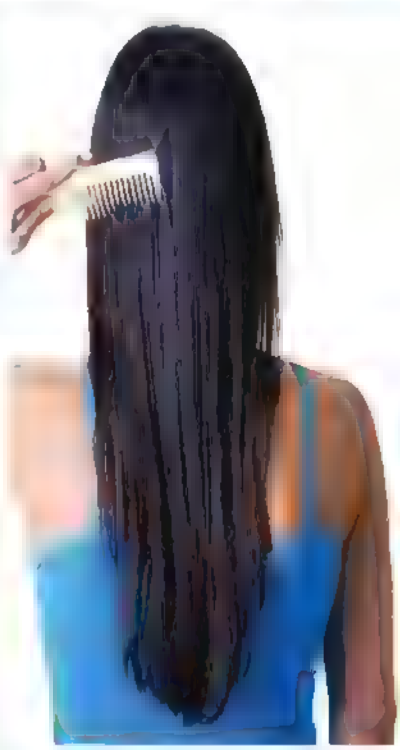
11 How fast does blood travel round the human body?

Your total 'circulating volume' is about five litres. Each red blood cell within this has to go from your heart, down the motorway-like arteries, through the back-road capillary system, and then back through the rush-hour veins to get back to your heart. The process typically takes about a minute. When you're in a rush and your heart rate shoots up, the time reduces as the blood diverts from the less-important structures (e.g. large bowel) to the more essential (e.g. muscles).



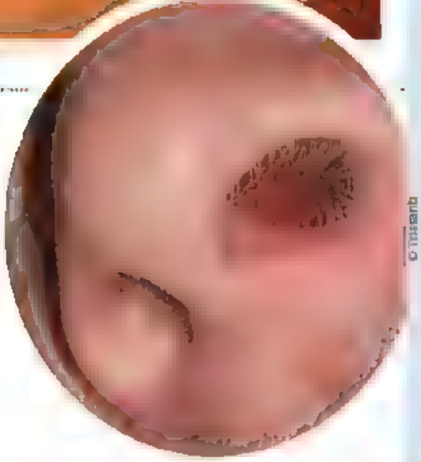
10 Why does it feel so weird when you hit your funny bone?

You're actually hitting the ulnar nerve as it wraps around the bony prominence of the 'humerus' bone, leading to a 'funny' sensation. Although, not so funny, as the brain interprets this sudden trauma as pain to your forearm and fingers!



13 How many inches of hair does the average person grow from their head each year?

It's different for everybody – your age, nutrition, health status, genes and gender all play a role. In terms of length, anywhere between 0.5-1 inch (1.2-2.5cm) a month tends to be considered average, but don't be surprised if you are outside of this range.

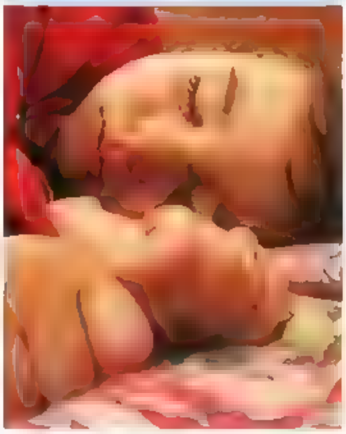


14 Why are everyone's fingerprints different?

Your fingerprints are fine ridges of skin in the tips of your fingers and toes. They are useful for improving the detection of small vibrations and to add friction for better grip. No two fingerprints are the same – either on your hands or between two people – and that's down to your unique set of genes.

15 Why do we only remember some dreams?

Dreams have fascinated humans for thousands of years. Some people think they are harmless while others think they are vital to our emotional wellbeing. Most people have four to eight dreams per night, which are influenced by stress, anxiety and desires, but they remember very few of them. There is research to prove that if you wake up during the rapid eye movement (REM) part of your sleep cycle, you're likely to remember your dreams more clearly.



16 Why, as we get older, does hair growth become so erratic?

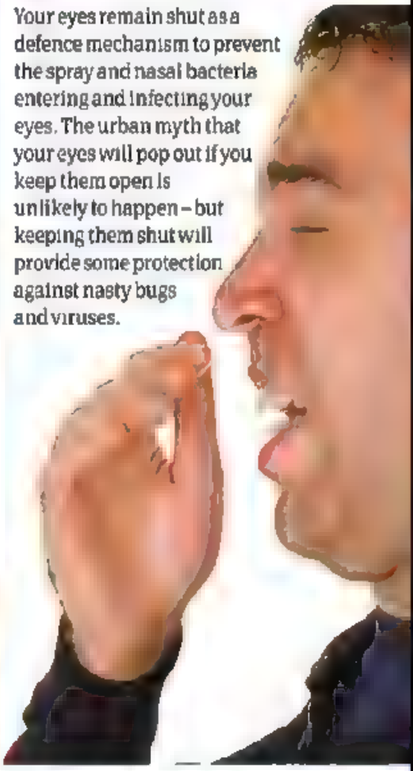
Hair follicles in different parts of your body are actually programmed by your genes to do different things, e.g. the follicles on your arm produce hair much slower than those on your head. Men can go bald due to a combination of genes and hormonal changes, which may not happen in other areas (e.g. nasal hair). It's different for everybody!

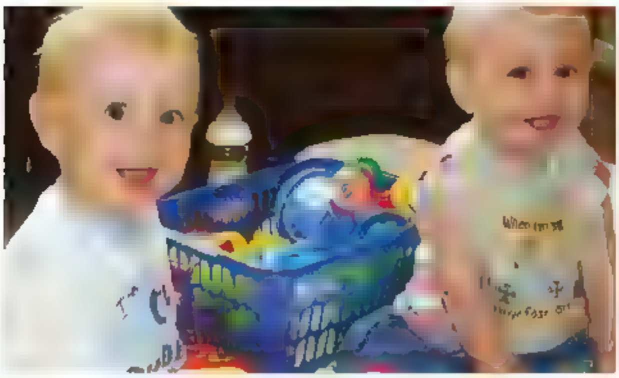
17 Why do we all have different coloured hair?

Most of it is down to the genes that result from when your parents come together to make you. Some hair colours win out (typically the dark ones) whereas some (e.g. blonde) are less strong in the genetic race.

18 Is it possible to keep your eyes open when you sneeze?

Your eyes remain shut as a defence mechanism to prevent the spray and nasal bacteria entering and infecting your eyes. The urban myth that your eyes will pop out if you keep them open is unlikely to happen – but keeping them shut will provide some protection against nasty bugs and viruses.





19 What gives me my personality?

Researchers have spent their whole lives trying to answer this one. Your personality forms in the front lobes of your brain, and there are clear personality types. Most of it is your environment – that is, your upbringing, education, surroundings. However, some of it is genetic, although it's unclear how much. The strongest research in this comes from studying twins – what influences one set of twins to grow up and be best friends, yet in another pair, one might become a professor and the other a murderer.

20 WHY DO MEN HAVE NIPPLES?

Men and women are built from the same template, and these are just a remnant of a man's early development.

21 WHAT'S THE POINT OF EYEBROWS?

Biologically, eyebrows can help to keep sweat and rainwater from falling into your eyes. More importantly in humans, they are key aids to non-verbal communication.

22 WHAT IS A BELLY BUTTON?

The umbilicus is where a baby's blood flows through to get to the placenta to exchange oxygen and nutrients with the mother's blood. Once out, the umbilical cord is clamped several centimetres away from the baby and left to fall off. No one quite knows why you'll get an 'innie' or an 'outie' – it's probably all just luck.

23 WHY IS IT THAT FINGERNAILS GROW MUCH FASTER THAN TOENAILS?

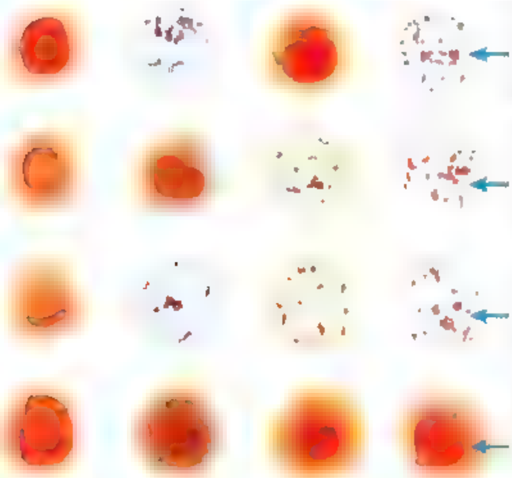
The longer the bone at the end of a digit, the faster the growth rate of the nail. However, there are many other influences too – nutrition, sun exposure, activity, blood supply – and that's just to name a few.

24 WHY DOES MY ARM TINGLE AND FEEL HEAVY IF I FALL ASLEEP ON IT?

This happens because you're compressing a nerve as you're lying on your arm. There are several nerves supplying the skin of your arm and three supplying your hand (the radial, median and ulnar nerves), so depending on which part of your arm you lie on, you might tingle in your forearm, hand or fingers.

25 What makes some blood groups incompatible while others are universal?

Your blood type is determined by protein markers, known as antigens, on the surface of your red blood cells. You can have A antigens, B antigens, or none – in which case you're blood type O. However, if you don't have the antigen, your antibodies will attack foreign blood. If you're type A and you're given B, your antibodies attack the B antigens. However, if you're blood type AB, you can safely receive any type. Those who are blood group O have no antigens so can give blood to anyone, but they have antibodies A and B so can only receive O back!



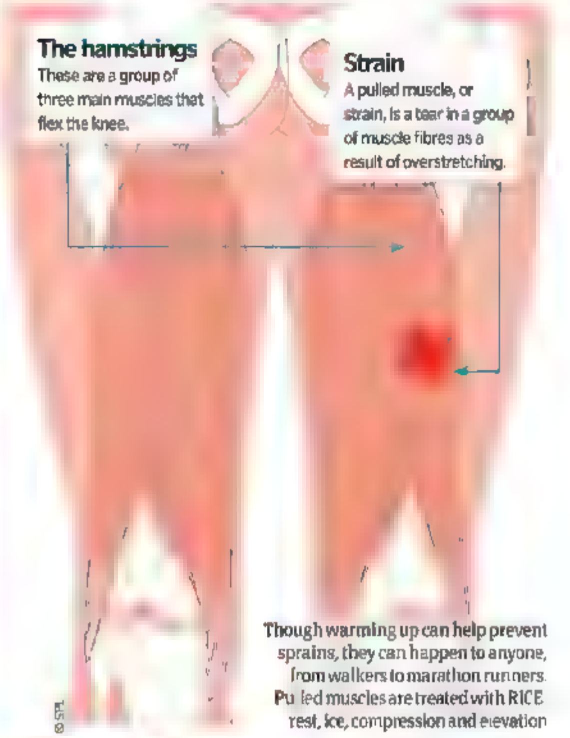
A
You have A antigens and B antibodies. You can receive blood groups A and O, but can't receive B. You can donate to A and AB.

B
You have B antigens and A antibodies. You can receive blood groups B and O, but can't receive A. You can donate to B and AB.

AB
You have A and B antigens and no antibodies. You can receive blood groups A, B, AB and O (universal recipient), and can donate to AB.

O
You have no antigens but have A and B antibodies. You can receive blood group O, but can't receive A, B or AB and can donate to all: A, B, AB and O.

26 What is a pulled muscle?



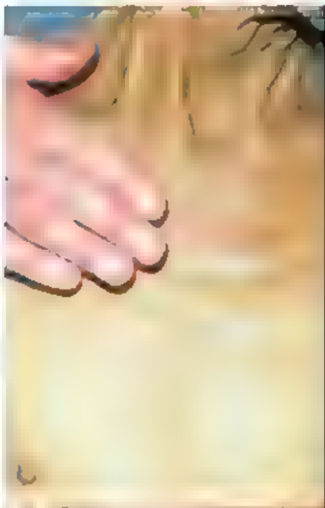
Though warming up can help prevent sprains, they can happen to anyone, from walkers to marathon runners. Pulled muscles are treated with RICE – rest, ice, compression and elevation

27 Which organ uses up the most oxygen?

The heart is the most efficient – it extracts 80 per cent of the oxygen from blood. But the liver gets the most blood – 40 per cent of the cardiac output compared to the kidneys, which get 25 per cent, and the heart, which only receives 5 per cent.

28 What is the appendix? I've heard it has no use but can kill you...

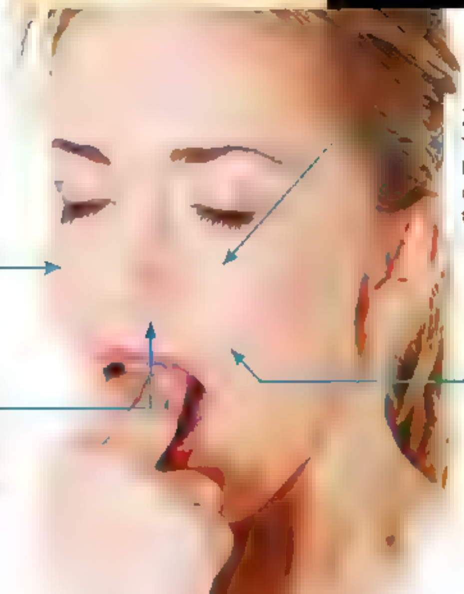
The appendix is useful in cows for digesting grass and koala bears for digesting eucalyptus – koalas can have a 4m (13ft)-long appendix! In humans, however, the appendix has no useful function and is actually a remnant of our development. It typically measures 5-10cm (1.9-3.9in), but if it gets blocked it can get inflamed. If it isn't quickly removed, the appendix can burst and lead to widespread infection which can be lethal.



29 Why does people's skin turn yellow if they contract liver disease?

This yellow discolouration of the skin or the whites of the eyes is called jaundice. It is actually due to a buildup of bilirubin within your body, when normally this is excreted in the urine (hence why urine has a yellow tint). Diseases such as hepatitis and gallstones can lead to a buildup of bilirubin due to altered physiological processes, but there are other causes.

30 What is the gag reflex?



1. Foreign bodies
This is a protective mechanism to prevent food or foreign bodies entering the back of the throat at times other than swallowing.

2. Soft palate
The soft palate (the fleshy part of the mouth roof) is stimulated, sending signals down the glossopharyngeal nerve.

3. Vagus nerve
The vagus nerve is stimulated, leading to forceful contraction of the stomach and diaphragm to expel the object forwards.

4. The gag
This forceful expulsion leads to 'gagging', which can develop into retching and vomiting.

31 Why are we ticklish?

Light touches by feathers, spiders, insects or other humans, can stimulate fine nerve-endings in the skin, which send impulses to the somatosensory cortex in the brain. Certain areas are more ticklish – such as the feet – which may indicate that it is a defence mechanism against unexpected predators. It is the unexpected nature of this stimulus that means you can be tickled. Although you can give yourself goosebumps through light tickling, you can't make yourself laugh

32 Why don't eyelashes keep growing?

Your eyelashes are formed from hair follicles, just like those on your head, arms and body. Each follicle is genetically programmed to function differently. Your eyelashes are programmed to grow to a certain length and even re-grow if they fall out, but they won't grow beyond a certain length, which is handy for seeing!

33 What makes us left-handed?

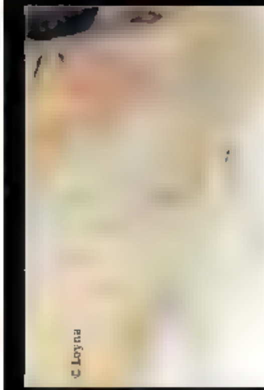
One side of the brain is more dominant over the other. Since each hemisphere of the brain controls the opposite side of your body, meaning the left controls the right side of your body. This is why right-handed people have stronger left brain hemispheres. However you can find an ambidextrous person, where hemispheres are co-dominant, and these people are equally capable with both right and left hands!

34 Could we survive on vitamins alone?

No, your body needs a diet balanced with vitamins, protein, minerals, carbs, and fat to survive. You can't cut one of these and expect your body to stay healthy. It is the proportions of these which keep us healthy and fit. You can get these from the five major food groups. Food charts can help with this balancing act.

35 Why do we get a high temperature when we're ill?

The immune response leads to inflammation and the release of inflammatory factors into your blood stream. These lead to an increased heart rate and blood flow, which increases your core body temperature – as if your body is doing exercise. This can lead to increased heat production and thus dehydration; for this reason, it's important to drink plenty of clear fluids when you're feeling unwell.



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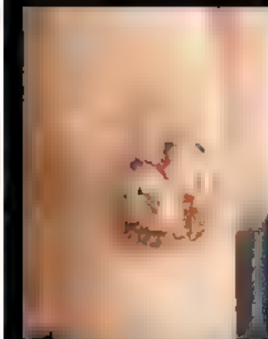
36 WHY DO SOME PEOPLE HAVE FRECKLES?

Freckles are concentrations of the dark skin pigment melanin in the skin. They typically occur on the face and shoulders, and are more common in light-skinned people. They are also a well-recognised genetic trait and become more dominant during sun-exposure.

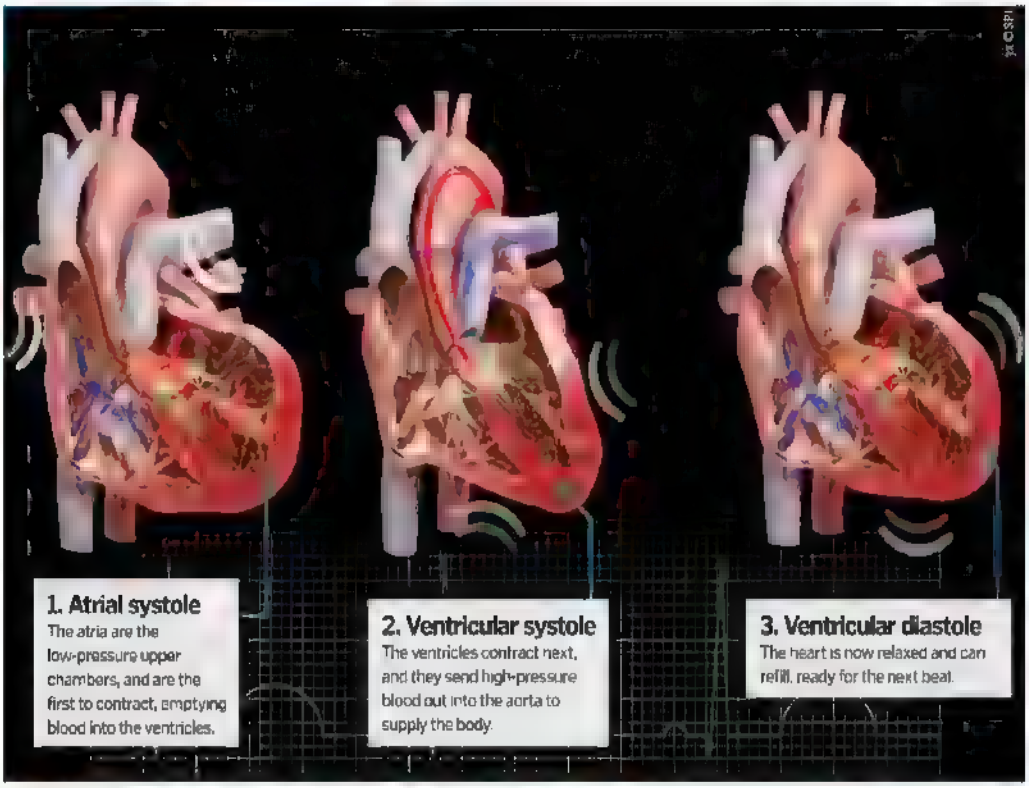


37 WHAT IS A WART?

Warts are small, rough, round growths of the skin caused by the human papilloma virus. There are different types which can occur in different parts of the body, and they can be contagious. They commonly occur on the hands, but can also come up anywhere from the genitals to the feet!

38 WHY DO I TWITCH IN MY SLEEP?

This is known in the medical world as a myoclonic twitch. Although some researchers say these twitches are associated with stress or caffeine use, they are likely to be a natural part of the sleep process. If it happens to you, it's perfectly normal.



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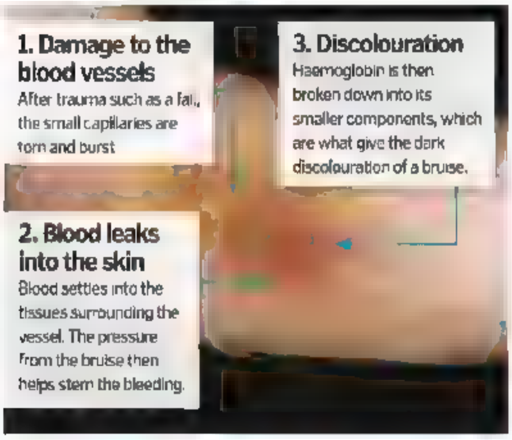
39 What triggers the heart and keeps it beating?

The heart keeps itself beating. The sinoatrial node (SAN) is in the wall of the right atrium of the heart, and is where the heartbeat starts. These beats occur due to changes in electrical currents as calcium, sodium and potassium move across membranes. The heart can beat at a rate of 60 beats per minute constantly if left alone. However – we often need it to go faster. The sympathetic nervous system sends rapid signals from the brain to stimulate the heart to beat faster when we need it to – in 'fight or flight' scenarios. If the SAN fails, a pacemaker can send artificial electrical signals to keep the heart going.

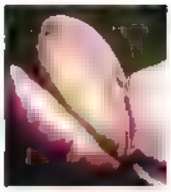
Definitions
Systole = contraction
Diastole = relaxation

40 Why do bruises go purple or yellow?

A bruise forms when capillaries under the skin leak and allow blood to settle in the surrounding tissues. The haemoglobin in red blood cells is broken down, and these by-products give a dark yellow, brown or purple discolouration depending on the volume of blood and colour of the overlying skin. Despite popular belief, you cannot age a bruise – different people's bruises change colour at different rates.



41 Why does cutting onions make us cry?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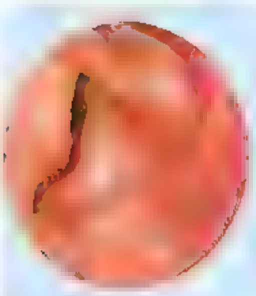
Onions make your eyes water due to their expulsion of an irritant gas once cut. This occurs because when an onion is cut with a knife, many of its internal cells are broken down, allowing enzymes to break down amino acid sulphoxides and generate sulphenic acids. These sulphenic acids are then rearranged by another enzyme and, as a direct consequence, syn-propanethial-S-oxide gas is produced, which is volatile. This volatile gas then diffuses in the air surrounding the onion, eventually reaching the eyes of the cutter, where it proceeds to activate sensory neurons and create a stinging sensation. As such, the eyes then follow protocol and generate tears from their tear glands in order to dilute and remove the irritant. Interestingly, the volatile gas generated by cutting onions can be largely mitigated by submerging the onion in water prior to or midway through cutting, with the liquid absorbing much of the irritant.

44 Why do more men go bald than women?

'Simple' male pattern baldness is due to a combination of genetic factors and hormones. The most implicated hormone is testosterone, which men have high levels of but women have low levels of, so they win (or lose?) in this particular hormone contest!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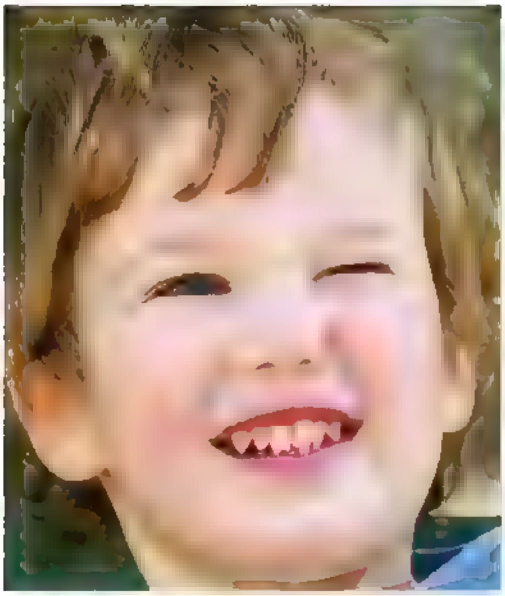
42 What is the little triangle shape on the side of the ear?

This is the tragus. It serves no major function that we know of, but it may help to reflect sounds into the ear to improve hearing.

43 When we're tired, why do we get bags under our eyes?

Blood doesn't circulate around your body as efficiently when you're asleep so excess water can pool under the eyes, making them puffy. Fatigue, nutrition, age and genes also cause bags.



45 Why do we blink?

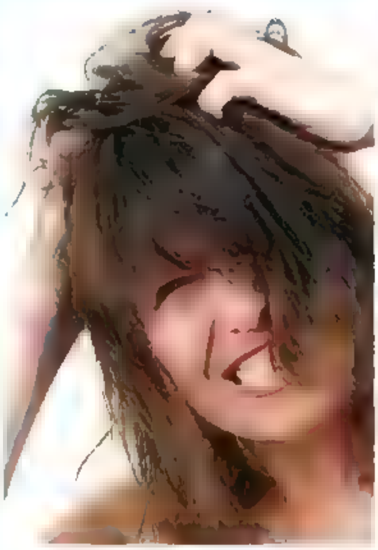
Blinking helps keep your eyes clean and moist. Blinking spreads secretions from the tear glands (lacrimal fluids) over the surface of the eyeball, keeping it moist and also sweeping away small particles such as dust.

46 How come most people have one foot larger than the other?

Most people's feet are different sizes – in fact the two halves of most people's bodies are different! We all start from one cell, but as the cells multiply, genes give them varying characteristics.

47 Why do we get itchy?

Itching is caused by the release of a transmitter called histamine from mast cells which circulate in your body. These cells are often released in response to a stimulus, such as a bee sting or an allergic reaction. They lead to inflammation and swelling, and send impulses to the brain via nerves, which causes the desire to itch.



48 Why do some hereditary conditions skip a generation?

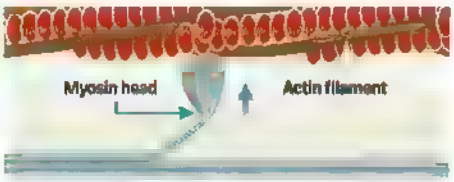
Genes work in pairs. Some genes are 'recessive' and if paired with a 'dominant' half, they won't shine through. However, if two recessive genes combine (one from your mother and one from your father), the recessive trait will show through.

49 Why do amputees sometimes still feel pain in their amputated limbs?

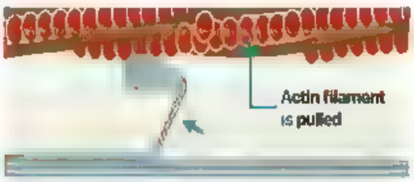
This is 'phantom limb pain' and can range from a mild annoyance to a debilitating pain. The brain can sometimes struggle to adjust to the loss of a limb, and it can still 'interpret' the limb as being there. Since the nerves have been cut, it interprets these new signals as pain. There isn't a surgical cure as yet, though time and special medications can help lessen the pain.

50 Which muscle produces the most powerful contraction relative to its size?

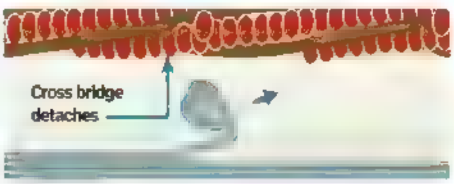
The gluteus maximus is the largest muscle and forms the bulk of your buttock. The heart (cardiac muscle) is the hardest-working muscle, as it is constantly beating and clearly can never take a break! However, the strongest muscle based on weight is the masseter. This is the muscle that clenches the jaw shut – put a finger over the lowest, outer part of your jaw and clench your teeth and you'll feel it.



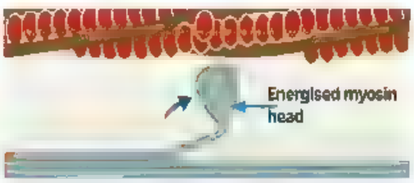
1. Taking the first step
Muscle contraction starts with an impulse received from the nerves supplying the muscle – an action potential. This action potential causes calcium ions to flood across the protein muscle fibres. The muscle fibres are formed from two key proteins: actin and myosin.



2. Preparation
The calcium binds to troponin, which is a receptor on the actin protein. This binding changes the shape of tropomyosin, another protein that is bound to actin. These shape changes lead to the opening of a series of binding sites on the actin protein.



3. Binding
Now the binding sites are free on actin, the myosin heads forge strong bonds in these points. This leads to the contraction of the newly formed protein complex; when all of the proteins contract, the muscle bulk contracts.



4. Unbinding
When the energy runs out, the proteins lose their strong bonds and disengage, and from there they return to their original resting state. This is the unbinding stage.

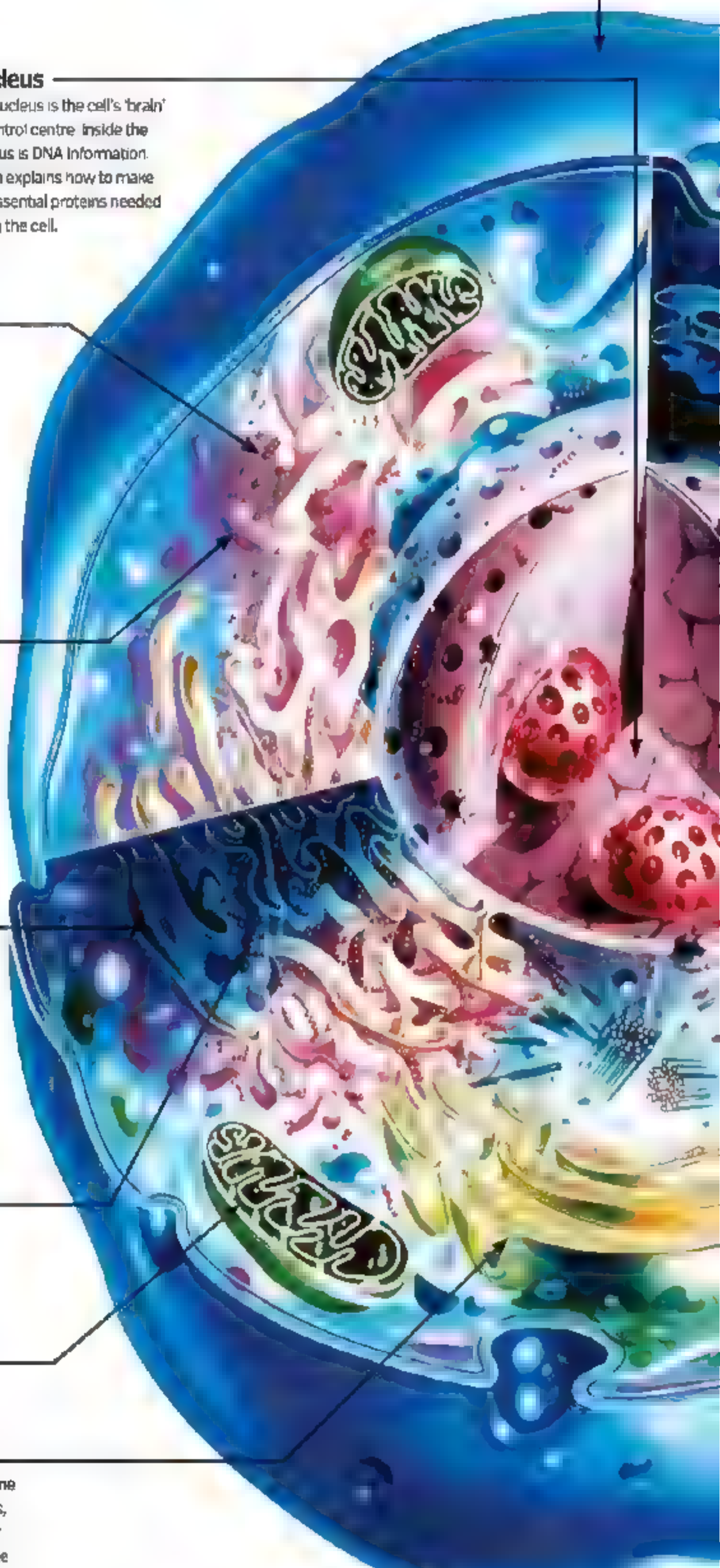
Cell structure explained

The human body has over 75 trillion cells, but what are they and how do they work?

Cells are life and cells are alive. You are here because every cell inside your body has a specific function and a very specialised job to do. There are many different types of cell, each one working to keep the body's various systems operating. A single cell is the smallest unit of living material in the body capable of life. When grouped together in layers or clusters, however, cells with similar jobs to do form tissue, such as skin or muscle. To keep these cells working, there are thousands of chemical reactions going on all the time.

All animal cells contain a nucleus, which acts like a control hub telling the cell what to do and contains the cell's genetic information (DNA). Most of the material within a cell is a watery, jelly-like substance called cytoplasm (cyto means cell), which circulates around the cell and is held in by a thin external membrane, which consists of two layers. Within the cytoplasm is a variety of structures called organelles, which all have different tasks, such as manufacturing proteins – the cell's key chemicals. One vital example of an organelle is a ribosome; these numerous structures can be found either floating around in the cytoplasm or attached to internal membranes. Ribosomes are crucial in the production of proteins from amino acids.

In turn, proteins are essential to building your cells and carrying out the biochemical reactions the body needs in order to grow and develop, and also to repair itself and heal.

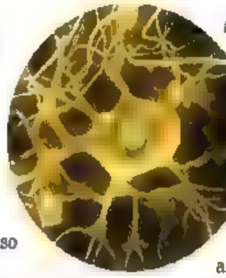


Cell anatomy

Types of human cell

So far, around 200 different varieties of cell have been identified, and they all have a very specific function to perform. Discover the main types and what they do…

NERVE CELLS

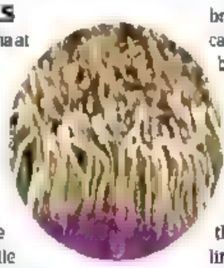


The cells that make up the nervous system and the brain are nerve cells or neurons. Electrical messages pass between nerve cells along long filaments called axons. To cross the gaps between nerve cells (the synapse) that electrical signal is converted into a chemical signal. These cells enable us to feel sensations, such as pain, and they also enable us to move.

BONE CELLS

The cells that make up bone matrix – the hard structure that makes bones strong – consist of three main types. Your bone mass is constantly changing and reforming and each of the three bone cells plays its part in this process. First the osteoblasts, which come from bone marrow, build up bone mass and structure. These cells then become buried in the matrix at which point they become known as osteocytes. Osteocytes make up around 90 per cent of the cells in your skeleton and are responsible for maintaining the bone material. Finally, while the osteoblasts add to bone mass, osteoclasts are the cells capable of dissolving bone and changing its mass.

PHOTORECEPTOR CELLS

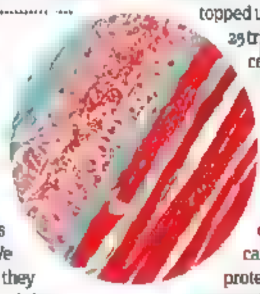


The cones and rods on the retina at the back of the eye are known as photoreceptor cells. These contain light-sensitive pigments that convert the image that enters the eye into nerve signals, which the brain interprets as pictures. The rods enable you to perceive light, dark and movement, while the cones bring colour to your world.

LIVER CELLS

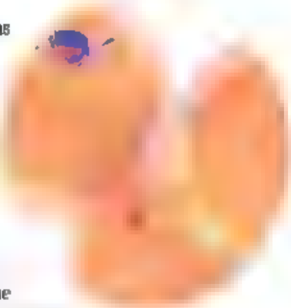
The cells in your liver are responsible for regulating the composition of your blood. These cells filter out toxins as well as controlling fat, sugar and amino acid levels. Around 80 per cent of the liver's mass consists of hepatocytes, which are the liver's specialised cells that are involved with the production of proteins and bile.

MUSCLE CELLS



There are three types of muscle cell – skeletal, cardiac and smooth – and each differs depending on the function it performs and its location in the body. Skeletal muscles contain long fibres that attach to bone. When triggered by a nerve signal, the muscle contracts and pulls the bone with it, making you move. We can control skeletal muscles because they are voluntary. Cardiac muscles, meanwhile, are involuntary, which is fortunate because they are used to keep your heart beating. Found in the walls of the heart, these muscles create their own stimuli to contract without input from the brain. Smooth muscles, which are pretty slow and also involuntary, make up the linings of hollow structures such as blood vessels and your digestive tract. Their wave-like contraction aids the transport of blood around the entire body and the digestion of food.

FAT CELLS

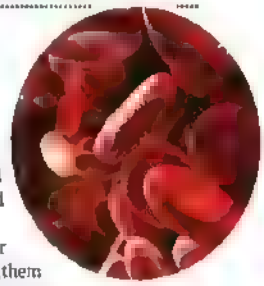


These cells – also known as adipocytes or lipocytes – make up your adipose tissue, or body fat, which can cushion, insulate and protect the body. This tissue is found beneath your skin and also surrounding your other organs. The size of a fat cell can increase or decrease depending on the amount of energy it stores. If we gain weight the cells fill with more watery fat, and eventually the number of fat cells will begin to increase. There are two types of adipose tissue: white and brown. The white adipose tissue stores energy and insulates the body by maintaining body heat. The brown adipose tissue, on the other hand, can actually create heat and isn't burned for energy – this is why animals are able to hibernate for months on end without food.

EPITHELIAL CELLS

Epithelial cells make up the epithelial tissue that lines and protects your organs and constitute the primary material of your skin. These tissues form a barrier between the precious organs and unwanted pathogens or other fluids. As well as covering your skin, you'll find epithelial cells inside your nose, around your lungs and in your mouth.

RED BLOOD CELLS



Unlike all the other cells in your body, your red blood cells (also known as erythrocytes) do not contain a nucleus. You are topped up with around 25 trillion red blood cells – that's a third of all your cells, making them the most common cell found in your body. Formed in the bone marrow, these cells are important because they carry oxygen to all the different tissues in your body. Oxygen is carried in haemoglobin, a pigmented protein that gives the blood cells their recognisable red colour.

Inside a nucleus

Dissecting the control centre of a cell

Surrounded by cytoplasm, the nucleus contains a cell's DNA and controls all of its functions and processes such as movement and reproduction.

There are two main types of cell: eukaryotic and prokaryotic. Eukaryotic cells contain a nucleus while prokaryotic do not. Some eukaryotic cells have more than one nucleus – called multinucleate cells – occurring when fusion or division creates two or more nuclei.

At the heart of a nucleus you'll find the nucleolus; this particular area is essential in the formation of ribosomes. Ribosomes are responsible for making proteins out of amino acids which take care of growth and repair.

The nucleus is the most protected part of the cell. In animal cells it is located near its centre and away from the membrane for maximum cushioning. As well as the jelly-like cytoplasm around it, the nucleus is filled with nucleoplasm, a viscous liquid which maintains its structural integrity.

Conversely, in plant cells, the nucleus is more sporadically placed. This is due to the fact that a plant cell has a larger vacuole and there is added protection which is granted by a cell wall.

Central command

Take a peek at what's happening inside the 'brain' of a eukaryotic cell

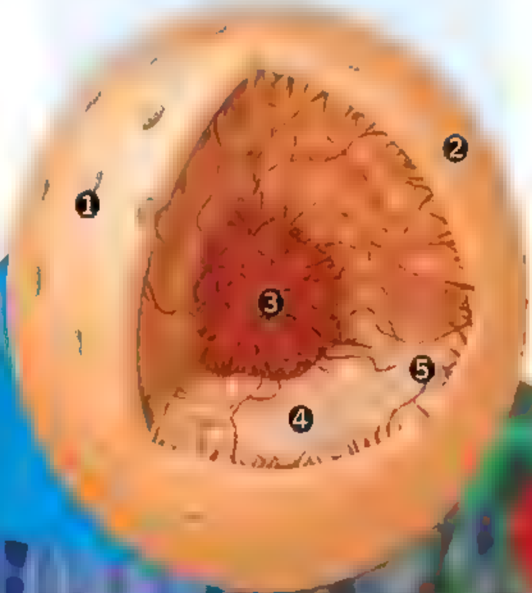
1 Nuclear pore
These channels control the movement of molecules between the nucleus and cytoplasm.

2 Nuclear envelope
Acts as a wall to protect the DNA within the nucleus and regulates cytoplasm access.

3 Nucleolus
Made up of protein and RNA, this is the heart of the nucleus which manufactures ribosomes.

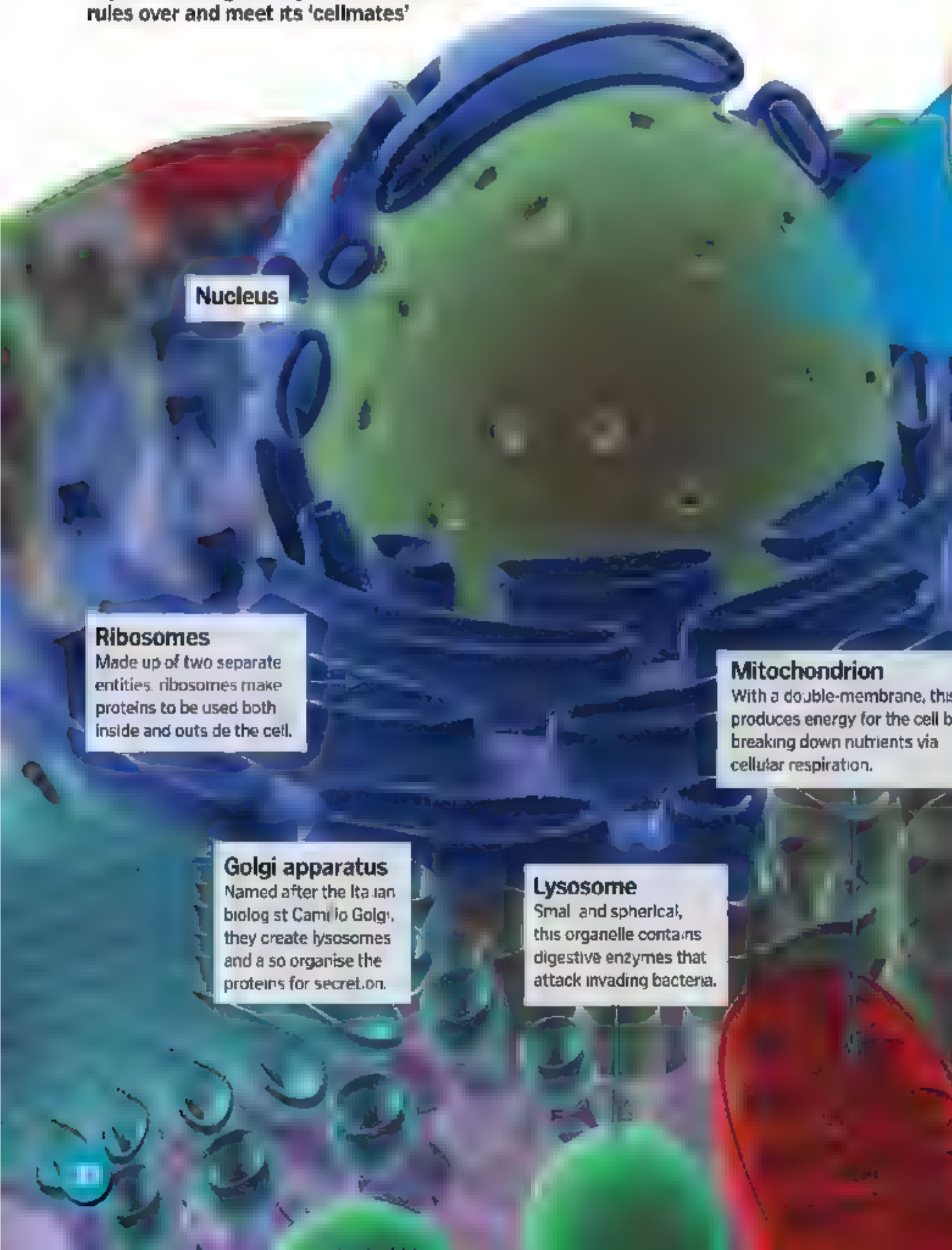
4 Nucleoplasm
This semi-liquid, semi-jelly material surrounds the nucleolus and keeps the organelle's structure.

5 Chromatin
Produces chromosomes and aids cell division by condensing DNA molecules.



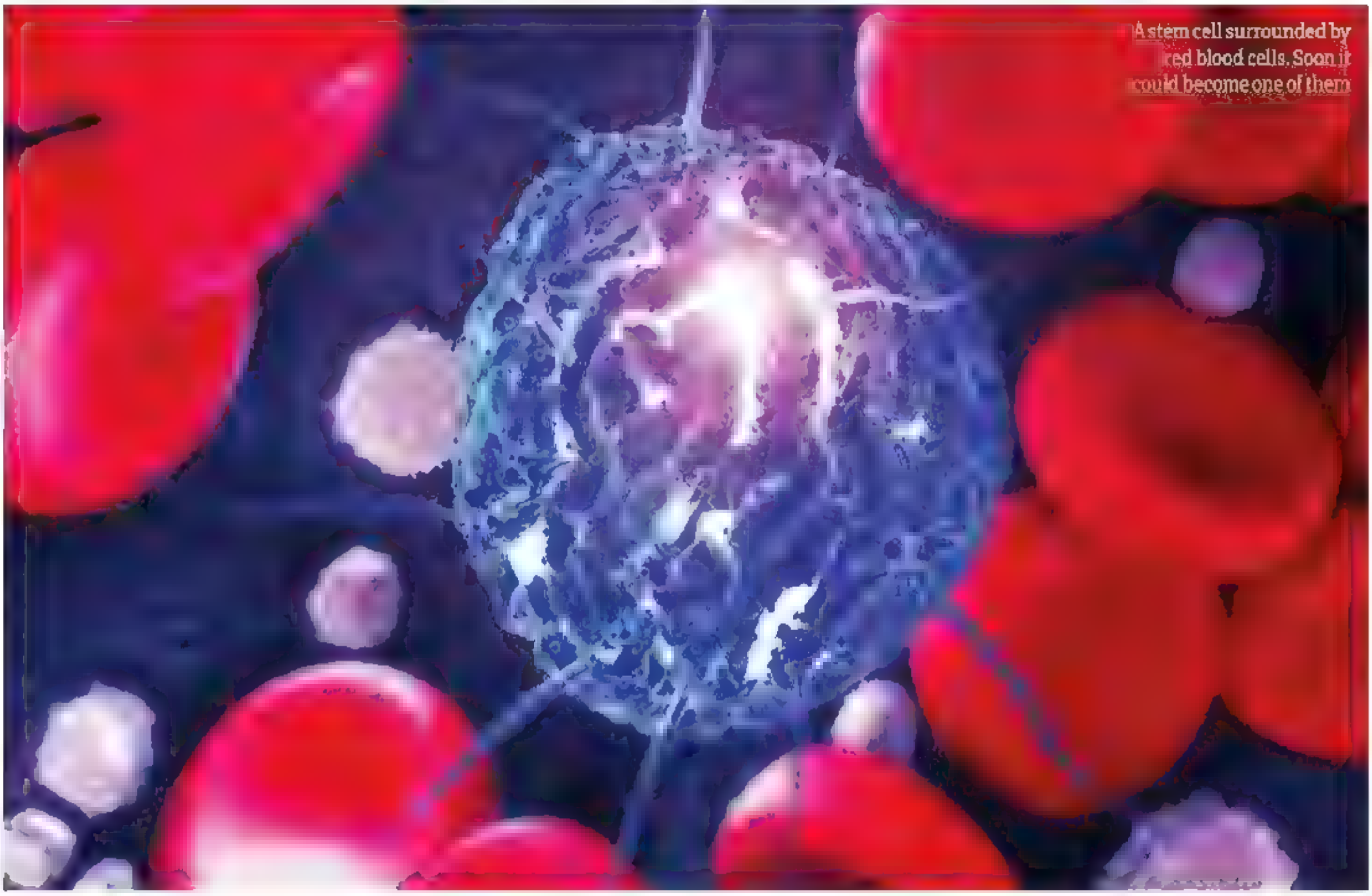
Nucleus in context

Explore the larger body that a nucleus rules over and meet its 'cellmates'



How do cells survive without a nucleus?

Prokaryotic cells are actually much more basic than their eukaryotic counterparts. Not only are they up to 100 times smaller but they also are mainly a comprising species of bacteria, prokaryotic cells have fewer functions than other cells, so they do not require a nucleus to act as the control centre for the organism. Instead, these cells have their DNA moving around the cell rather than being housed in a nucleus. They have no chloroplasts, no membrane-bound organelles and they don't undertake cell division in the form of mitosis or meiosis like eukaryotic cells do. Prokaryotic cells divide asexually with DNA molecules replicating themselves in a process that is known as binary fission.



A stem cell surrounded by red blood cells. Soon it could become one of them

What are stem cells?

Understand how these building blocks bring new life

Stem cells are incredibly special because they have the potential to become any kind of cell in the body, from red blood cells to brain cells. They are essential to life and growth, as they repair tissues and replace dead cells. Skin, for example, is constantly replenished by skin stem cells.

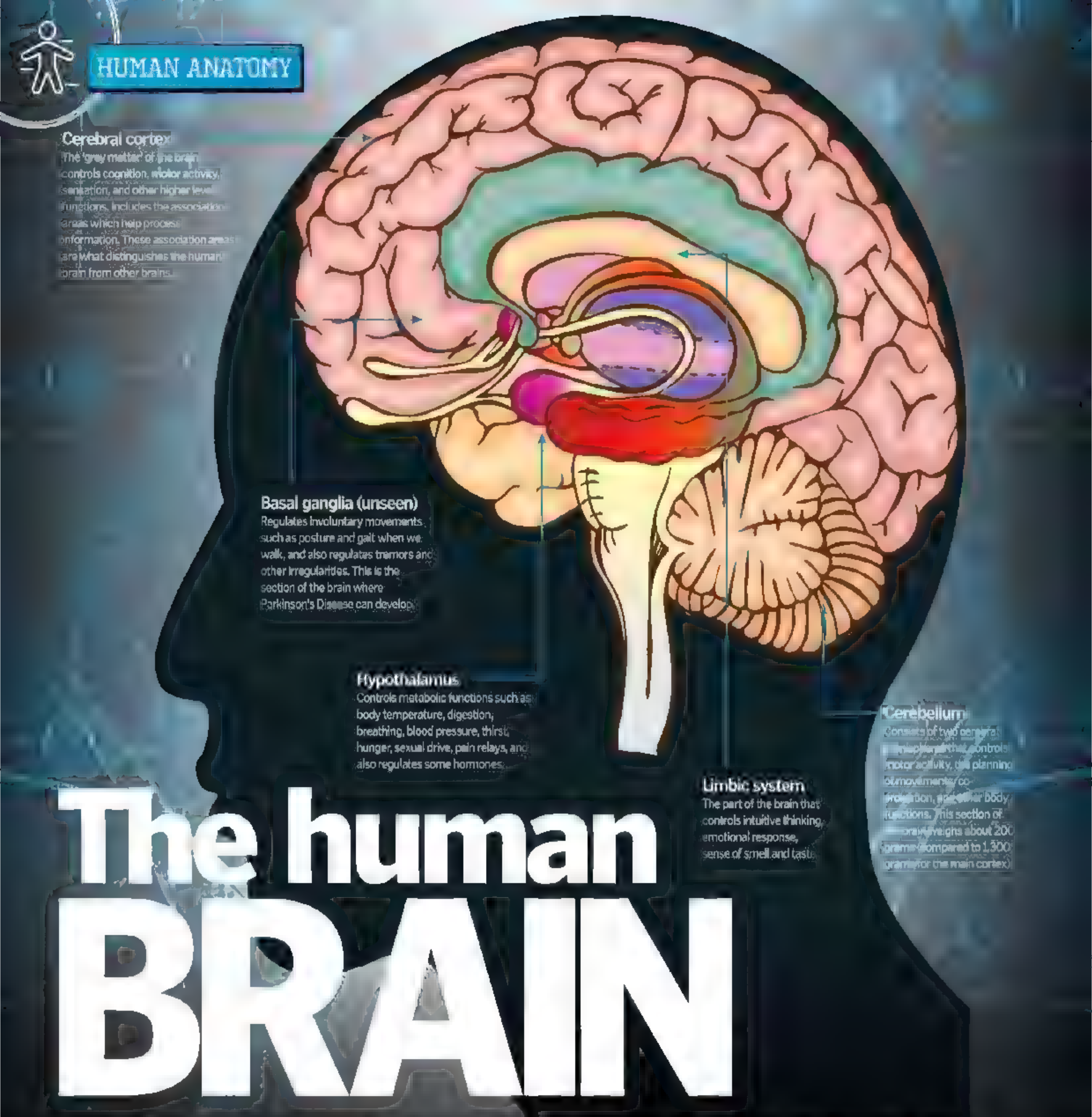
Stem cells begin their life cycle as generic, featureless cells that don't contain tissue-specific structures, such as the ability to carry oxygen. Stem cells become specialised through a process called differentiation. This is triggered by signals inside and outside the cell. Internal signals come from strands of DNA that carry information for all cellular structures, while external signals include chemicals from nearby cells. Stem cells can replicate many times – known as proliferation – while others such as nerve cells don't divide at all.

There are two stem cell types, as Professor Paul Fairchild, co-director of the Oxford Stem Cell Institute at Oxford Martin School explains: "Adult stem cells are multipotent, which means they are able to produce numerous cells that are loosely related, such as stem cells in the bone marrow can generate cells that make up the blood," he says. "In contrast, pluripotent stem cells, found within developing embryos, are able to make any one of the estimated 210 cell types that make up the human body."

This fascinating ability to transform and divide has made stem cells a rich source for medical research. Once their true potential has been harnessed, they could be used to treat a huge range of diseases and disabilities.

Cloning cells

[illegible] forget their current [illegible] become pluripotent cell [illegible] indistinguis [illegible] Parkinson's disease and ba [illegible] which are caused by cells [illegible] without being replaced. The iPS [illegible] fill these gaps in order to res [illegible] the body's sys [illegible] investigate the effects [illegible] drugs on that disea [illegible]



The human BRAIN

Described as the most complex thing in the universe, our brains are truly astonishing

The brain makes up just two per cent of our total body weight, but crammed inside are approximately 86 billion neurons, surrounded by 180,000 kilometres of insulated fibres connected at 100 trillion synapses. It's a vast biological supercomputer.

The cells in the brain communicate using electrical signals. When a message is sent, thousands of microscopic channels open, allowing positively charged ions to flood across the membrane. Afterwards, more than 1 million miniature pumps in each cell move the ions back again ready for the next impulse.

The cell bodies of the neurons, and their connections, are contained within the grey matter, which consumes 94 per cent of the oxygen delivered to the brain. Different areas are responsible for different functions, and wiring them together is a fatty network of fibres called white matter.

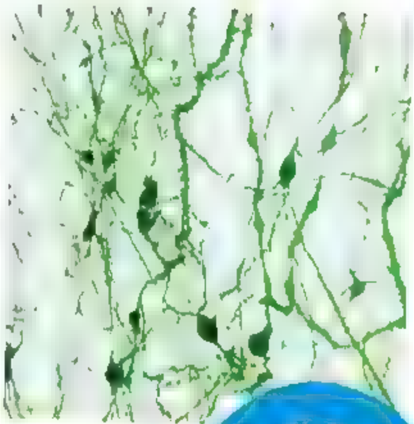
When a signal reaches the end of a nerve cell, tiny packets of chemical signals spill out onto the surrounding neurons. These connections, called synapses, allow messages to be passed from one cell to the next. Each neuron can receive thousands of inputs, coordinating them in time and space, and by type of chemical, to decide what to do next.

Scientists have been electrically and chemically stimulating the brain to see how it responds to different signals, recording electrical activity to map thoughts and using imaging like functional MRI to track the blood flow increases that reveal when nerve cells are firing. The cells of the brain can also be studied inside the lab. Thanks to these investigations, we know more about this incredible structure than ever before, but our understanding is only just beginning. There is so much more to learn.

Brain development

From a single cell to an incredibly intricate network in just nine months

Within weeks of fertilisation, neural progenitors start to form; these stem cells will go on to become all of the cells of the central nervous system. They organise into a neural tube when the embryo is barely the size of a pen tip, and then patterning begins, laying out the structural organisation of the brain and spinal cord. At its peak growth rate, the developing brain can generate 250,000 new neurons every minute. By the time a baby is born, the process still isn't complete. But, by the age of two, the brain is 80 per cent of its adult size.

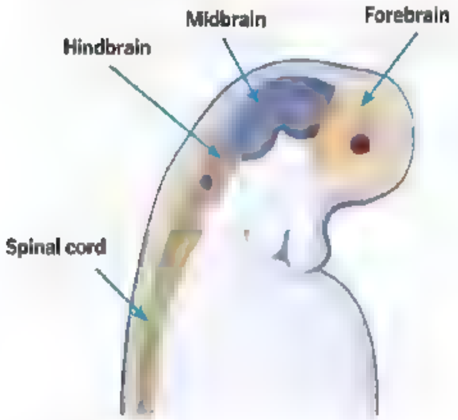


Pyramidal neurons, like these, are found in the hippocampus, cortex and amygdala

20 watts
Your brain is incredibly [illegible]fficient, using le[illegible] energy than a standard lightbulb

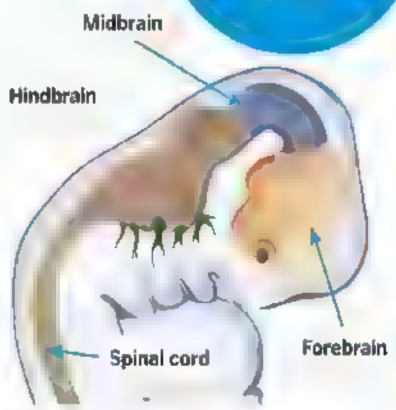
Brain formation

This astonishing structure is formed and refined as pregnancy progresses



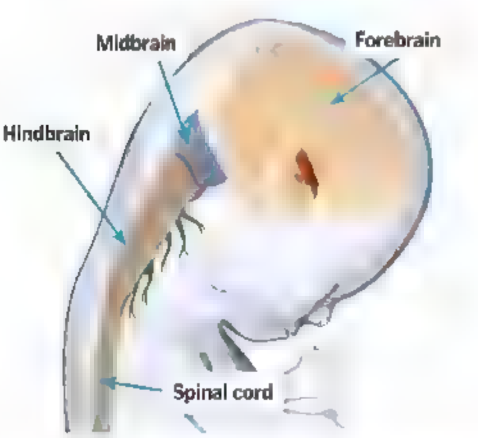
4 weeks

Brain development starts just three weeks after fertilisation. The first structure is the neural tube, which divides into regions that later become the forebrain, midbrain, hindbrain and spinal cord.



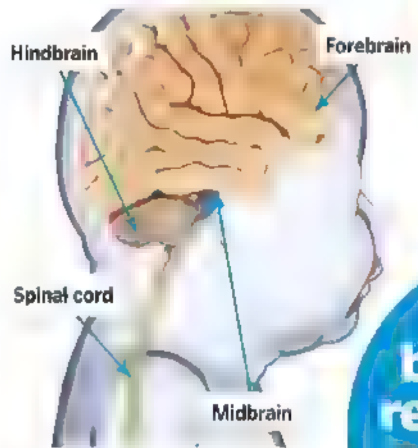
6 weeks

The pattern of the brain and spinal cord is now laid out and is gradually refined, controlled by gradients of signalling molecules that assign different areas for different functions



11 weeks

As the embryo becomes larger, the brain continues to increase in size and neurons migrate and organise. The surface of the brain gradually begins to fold. At this point, a foetus only measures about five centimetres in length.



Birth

Before a baby is born, around half of the nerve cells in the brain are lost and connections are pruned, leaving only the most useful. This process continues after birth.

Why the brain is wrinkled

The brain folds in on itself to cram in more processing power

The folds and pockets of our brains are a biological rarity that we only share with a few other species, including dolphins, some primates and elephants. It's a clever [illegible]lutionary adaptation that a[illegible] intelligen[illegible] to squash a huge amount of cortical tissue into a small space, allo[illegible] brainpower to be crammed into our re[illegible] [illegible]all skulls. Folding starts during the second trim[illegible]er of pregnancy, creating ridges (gyri) and f[illegible] (sulci), but the biology behind the distinct[illegible] wrinkles is stranger than you might think. T[illegible] organisation of the brain is determined by complex cascade[illegible] of chemical signals, but the overall shape seems to be the [illegible] [illegible]imple physics. [illegible]y matter sits on the out[illegible]de of the brain and, during [illegible]opment, its growth rapidly outpaces the growth of white matter underneat[illegible]. This puts mechanical stress on the [illegible]ructure, forcing the outside to buckle and curl.

More wrinkled brains are associated with higher intelligence (brain sizes not to sca[illegible]

"Our brains contain 86 billion neurons and 180,000 kilometres of fibres"

The brain can regenerate
Certain areas of the adult brain can continue to produce new neurons, a process known as neurogenesis

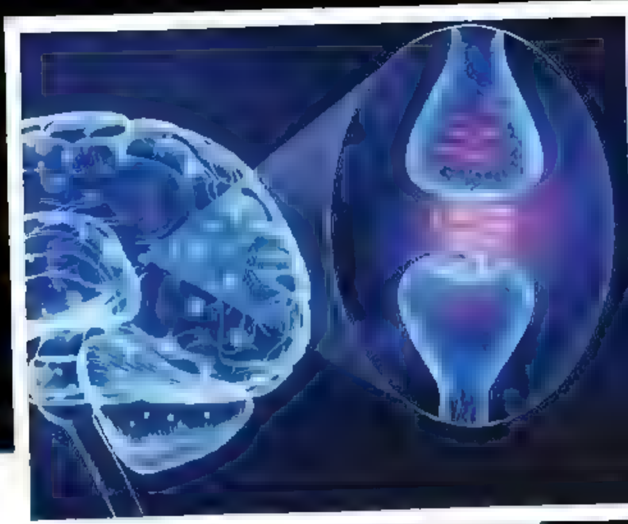
Making memories

The brain can store around 1 million gigabytes of data

A team at the Salk Institute in California estimate that the brain can store around 1 petabyte of information, stuffed into the connections between nerve cells. That's around 2,000 years worth of MP3 music or 223,000 DVDs. And, incredibly, it's possible to watch memories being made.

The Weizmann Institute in Israel and UCLA in the US captured memory formation in action. Patients watched clips of videos and were then asked to recall what they'd seen. The neurons that lit up when they watched the first time lit up again as they relived the experience inside of their heads – a bit like an echo in the brain.

Recent research from the US and Japan suggests that these echoes are actually stored twice – once in the hippocampus and again in the cortex. The hippocampus handles short-term storage and gradually forgets, but as it does so it helps to reinforce the memory in the cortex, allowing long-term recall.



Neurons make new connections when a memory is formed

Self-cleaning brains

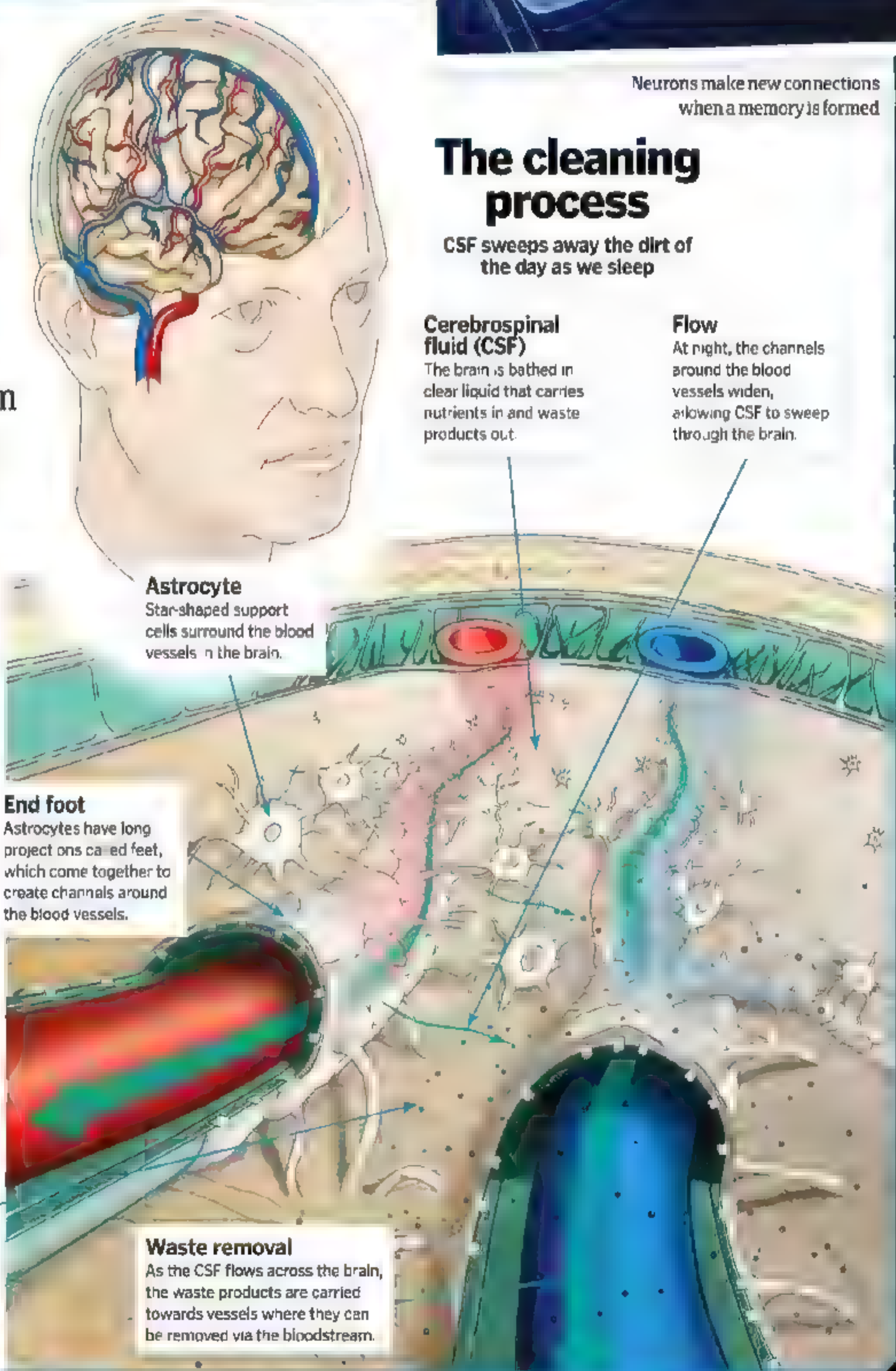
We have a built-in system to clear toxic waste from between our brain cells

Sleep is one of the brain's great mysteries, but research on mice has revealed an intriguing night time cleanup system. The brain is shielded by a barrier made and maintained by cells called astrocytes. They hug the blood vessels, controlling what's allowed in and out, and a space between the vessel wall and these cells seems to play a crucial role in keeping the brain clean.

At night, the astrocytes relax their grip and the space fills up with a clear liquid called cerebrospinal fluid (CSF). It's pushed along by the movement of the blood vessels underneath, swishing up through the astrocytes and out into the spaces between brain cells. As it passes, it picks up waste and debris, carrying the particles back towards the bloodstream so that they can be removed from the brain.

The cleaning process

CSF sweeps away the dirt of the day as we sleep



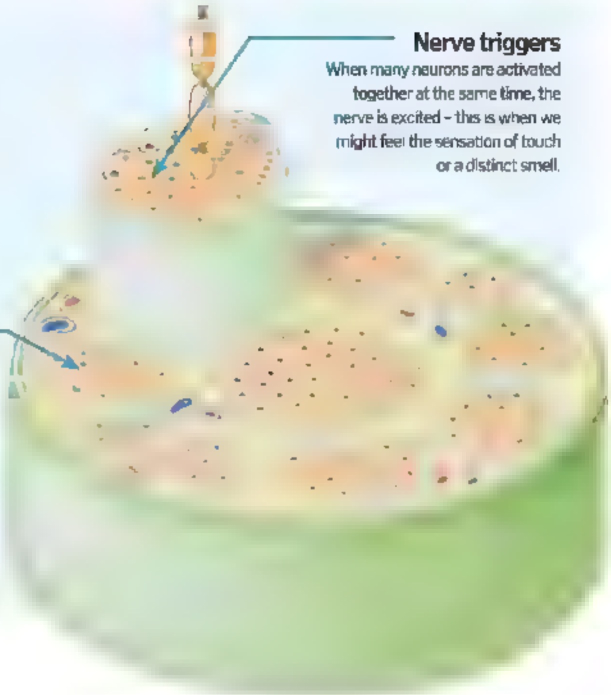
How do nerves work?

Nerves carry signals throughout the body – a chemical superhighway

Nerves are the transmission cables that carry brain waves in the human body, says Sol Diamond, an assistant professor at the Thayer School of Engineering at Dartmouth. According to Diamond, nerves communicate these signals from one point to another, whether from your toenail up to your brain or from the side of your head.

Nerve transmissions
Some nerve transmissions travel great distances through the human body, others travel short distances – both use a de-polarisation to create the circuit. De-polarisation is like a wound-up spring that releases stored energy once it's triggered.

Myelinated and un-myelinated
Some nerves are myelinated (or insulated) with fatty tissue that appears white and forms a slower connection over a longer distance. Others are un-myelinated and are un-insulated. These nerves travel shorter distances.

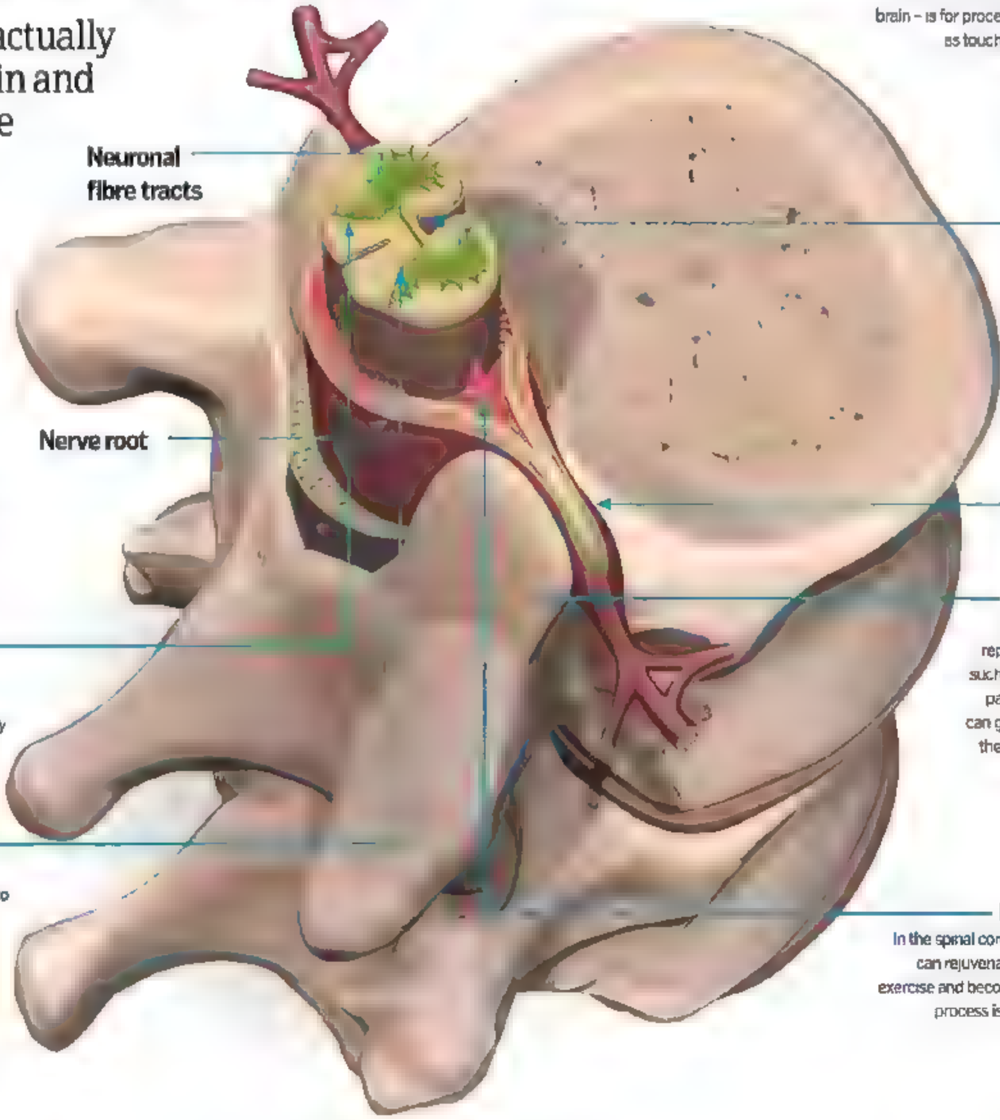


Nerve triggers
When many neurons are activated together at the same time, the nerve is excited – this is when we might feel the sensation of touch or a distinct smell.

What does the spinal cord do?

The spinal cord actually is part of the brain and plays a major role

Scientists have known for the past 100 years or so that the spinal cord is actually part of the brain. According to Melillo, while the brain has grey matter on the outside (protected by the skull) and protected white matter on the inside, the spinal cord is the reverse: the grey matter is inside the spinal cord and the white matter is outside.



Spinal cord core
In the core of the spinal cord, grey matter – like the kind in the outer layer of the brain – is for processing nerve cells such as touch, pain and movement.

Grey matter cells
Grey matter cells in the spinal cord cannot regenerate, which is why people with a serious spinal cord injury cannot recover over a period of time. White matter cells can re-generate.

White matter cells
White matter cells in the spinal cord carry the electro-chemical pulses up to the brain. For example, when you are kicked in the shin, you feel the pain in the shin and your brain then tells you to move your hand to cover that area.

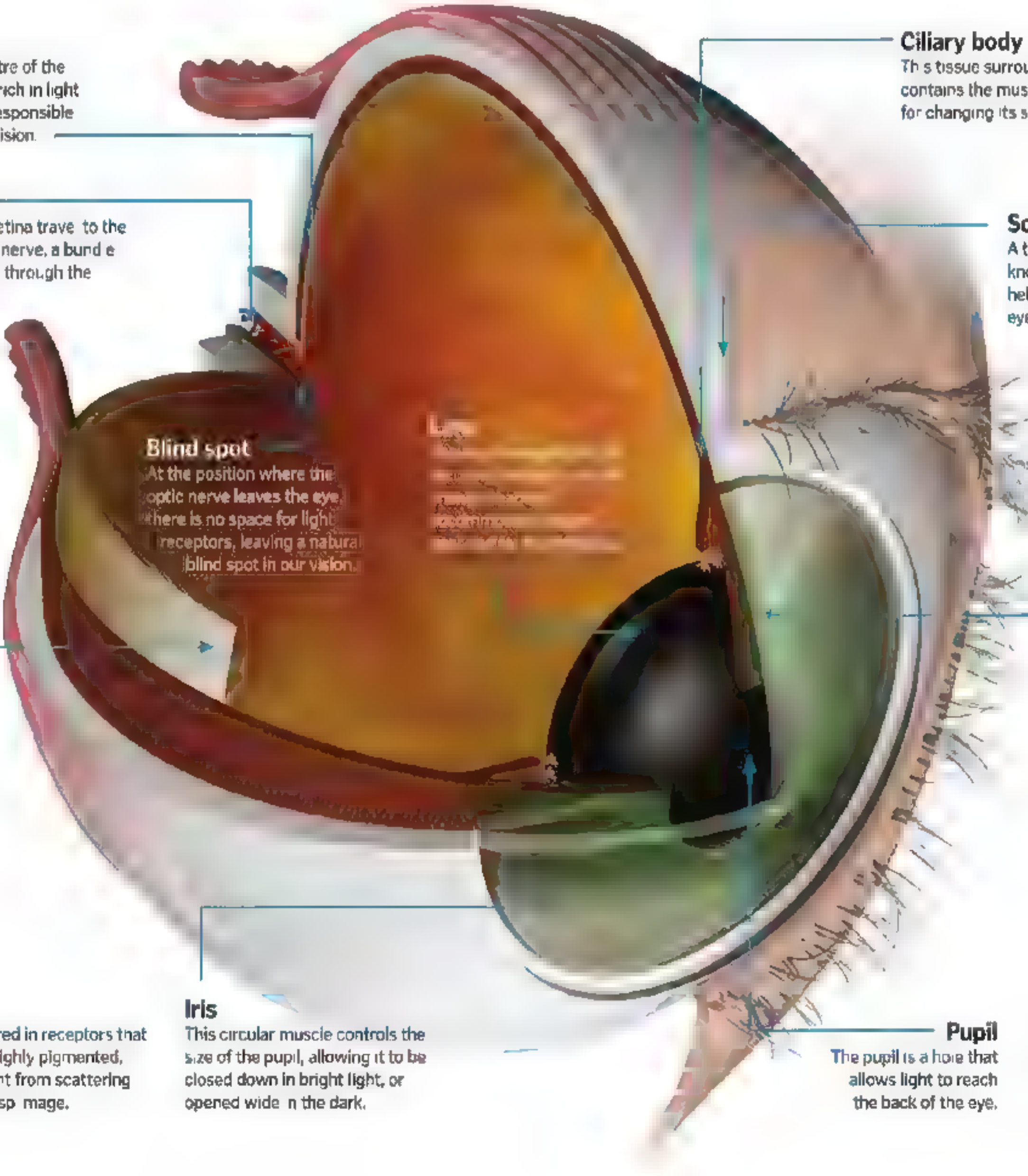
Neurogenesis
According to Tallai, by repeating brain activities such as memorisation and pattern recognition, you can grow new brain cells in the spinal cord and brain.

Neuroplasticity
In the spinal cord and in the brain, cells can rejuvenate over time when you exercise and become strengthened. This process is called neuroplasticity.

Inside the human eye

Uncovering one of the most complex constructs in the natural world

The structure of the human eye is so incredibly complex that it's actually hard to believe that it's not the product of intelligent design. But by looking at and studying the eyes of various other animals, scientists have been able to show that eyes have evolved very gradually from just a simple light-dark sensor over the course of around 100 million years. The eye functions in a very similar way to a camera, with an opening through which the light enters, a lens for focusing and a light-sensitive membrane. The amount of light that enters the eye is controlled by the circular and radial muscles in the iris, which contract and relax to alter the size of the pupil. The light first passes through a tough protective sheet called the cornea, and then moves into the lens. This adjustable structure bends the light, focusing it down to a point on the retina, at the back of the eye. The retina is covered in millions of light-sensitive receptors known as rods and cones. Each receptor contains pigment molecules, which change shape when they are hit by light, which triggers an electrical message that then travels to the brain via the optic nerve.



How the eye focuses

The tiny rings of muscle that make your vision sharp

Cameras and human eyes both focus light using a lens. This structure bends the incoming wavelengths so that they hit the right spot on a photographic plate, or on the back of the eye. A camera lens is made from solid glass, and focuses on near and distant objects by physically moving closer or further away. A biological lens is actually squishy, and it focuses by physically changing shape.

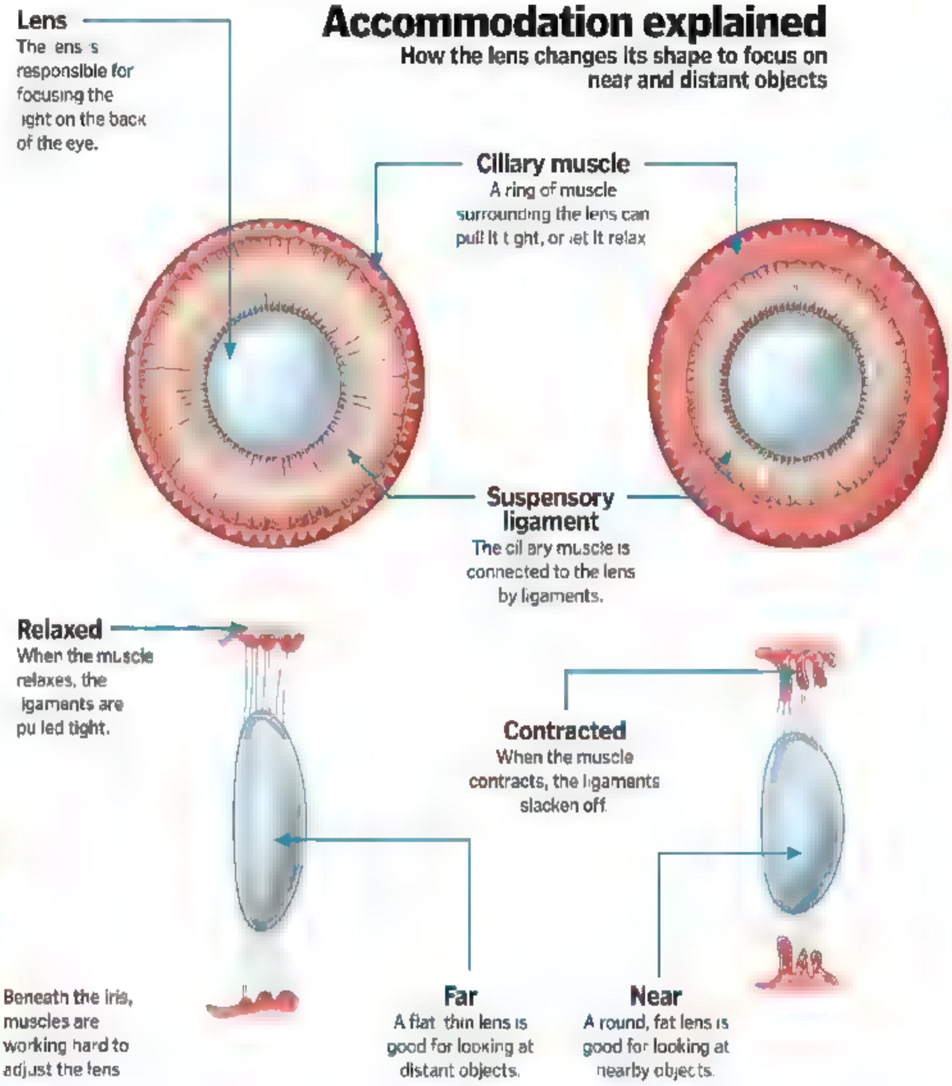
In the eye, this process is known as 'accommodation', and is controlled by a ring of smooth muscle called the ciliary muscle. This is attached to the lens by fibres known as suspensory ligaments. When the muscle is relaxed, the ligaments pull tight, stretching the lens until it is flat and thin. This is perfect for looking at objects in the distance.

When the ciliary muscle contracts, the ligaments loosen, allowing the lens to become fat and round. This is better for looking at objects that are nearby. The coloured part of the eye (called the iris) controls the size of the pupil and ensures the right amount of light gets through the lens.

Beneath the iris, muscles are working hard to adjust the lens

Accommodation explained

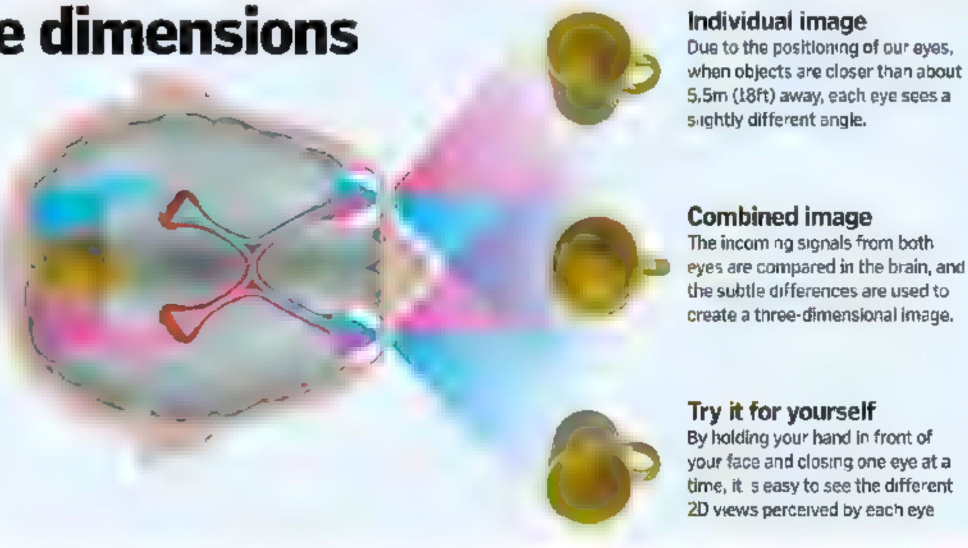
How the lens changes its shape to focus on near and distant objects



Seeing in three dimensions

Each eye sees a slightly different image, allowing the brain to perceive depth

Our eyes are only able to produce two-dimensional images, but with some clever internal processing, the brain is able to build these flat pictures into a three-dimensional view. Our eyes are positioned about five centimetres (two inches) apart, so each sees the world from a slightly different angle. The brain then compares the two pictures, using the differences to create the illusion of depth.



How ears work

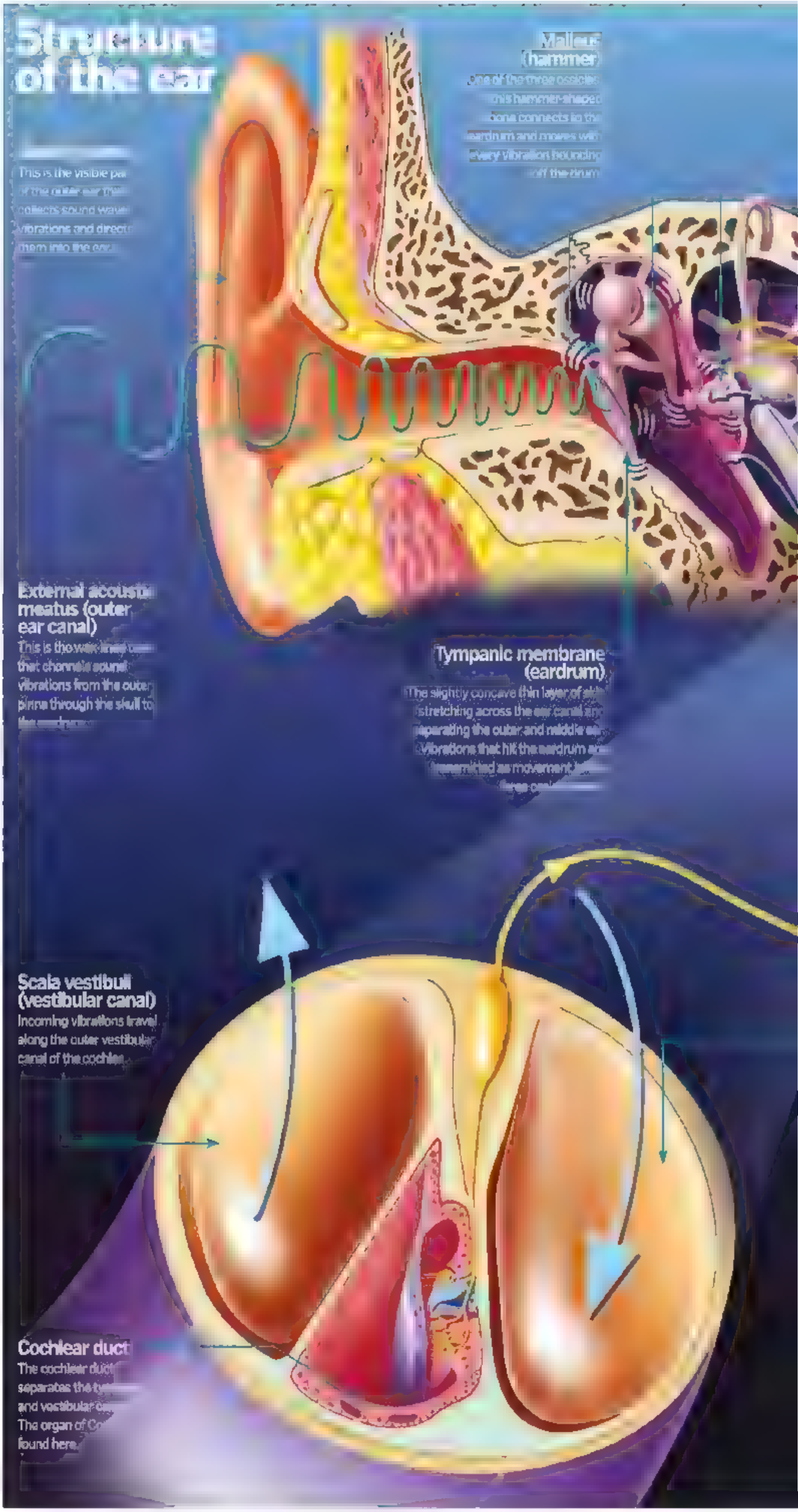
The human ear performs a range of functions, but how do they work?

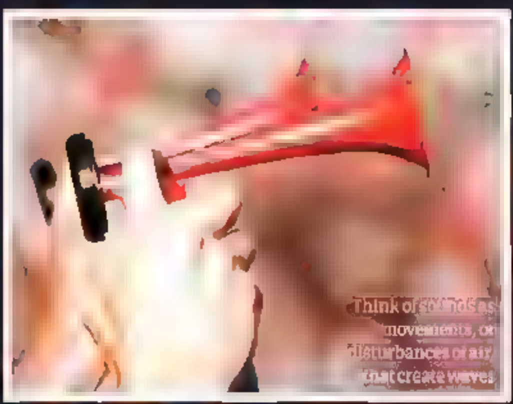
The thing to remember when learning about the human ear is that sound is all about movement. When someone speaks or makes any kind of movement, the air around them is disturbed, creating a sound wave of alternating high and low frequency. These waves are detected by the ear and interpreted by the brain as words, tunes or sounds.

Consisting of air-filled cavities, labyrinthine fluid-filled channels and highly sensitive cells, the ear has external, middle and internal parts. The outer ear consists of a skin-covered flexible cartilage flap called the 'auricle', or 'pinna'. This feature is shaped to gather sound waves and amplify them before they enter the ear for processing and transmission to the brain. The first thing a sound wave entering the ear encounters is the sheet of tightly pulled tissue separating the outer and middle ear. This tissue is the eardrum, or tympanic membrane, and it vibrates as sound waves hit it.

Beyond the eardrum, in the air-filled cavity of the middle ear, are three tiny bones called the 'ossicles'. These are the smallest bones in the human body. Sound vibrations hitting the eardrum pass to the first ossicle, the malleus (hammer). Next the waves proceed along the incus (anvil) and then on to the (stapes) stirrup. The stirrup presses against a thin layer of tissue called the 'oval window', and this membrane enables sound waves to enter the fluid-filled inner ear.

The inner ear is home to the cochlea, which consists of watery ducts that channel the vibrations, as ripples, along the cochlea's spiralling tubes. Running through the middle of the cochlea is the organ of Corti, which is lined with minute sensory hair cells that pick up on the vibrations and generate nerve impulses that are sent to the brain as electrical signals. The brain can interpret these signals as sounds.





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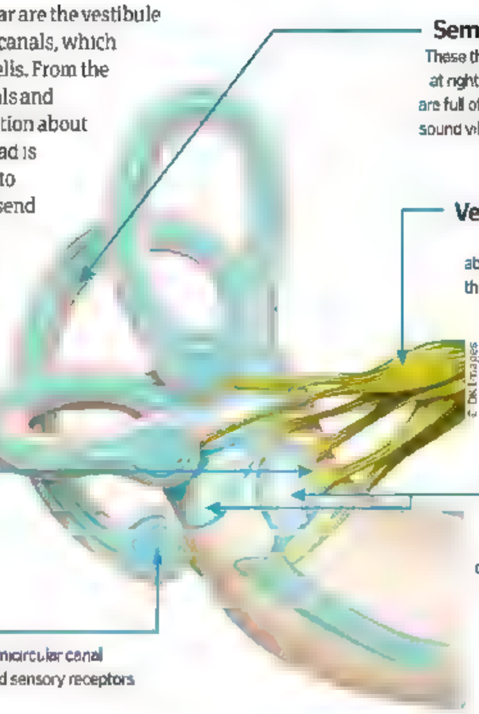
The vestibular system

Inside the inner ear are the vestibule and semicircular canals, which feature sensory cells. From the semicircular canals and maculae, information about which way the head is moving is passed to receptors, which send electrical signals to the brain as nerve impulses.



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A sense of balance

The vestibular system functions to give you a sense of which way your head is pointing in relation to gravity. It enables you to discern whether your head is upright or not, as well as helping you to maintain eye contact with stationary objects while your head is turning.

Also located within the inner ear, but less to do with sound and more concerned with the movement of your head, are the semicircular canals. Again filled with fluid, these looping ducts act like internal accelerometers that can actually detect acceleration (ie, movement of your head) in three different directions due to the positioning of the loops along different planes. Like the organ of Corti, the semicircular canals employ tiny hair cells to sense movement. The canals are connected to the auditory nerve at the back of the brain.

Your sense of balance is so complex that the area of your brain that's purely dedicated to this one role involves the same number of cells as the rest of your brain cells put together.

Your Skeleton

This incredible living framework provides more than just structural support

The 206 bones of the adult human skeleton make up a strong, flexible framework that protects our vital organs and allows our bodies to move, as well as being a mineral store and stem-cell reserve.

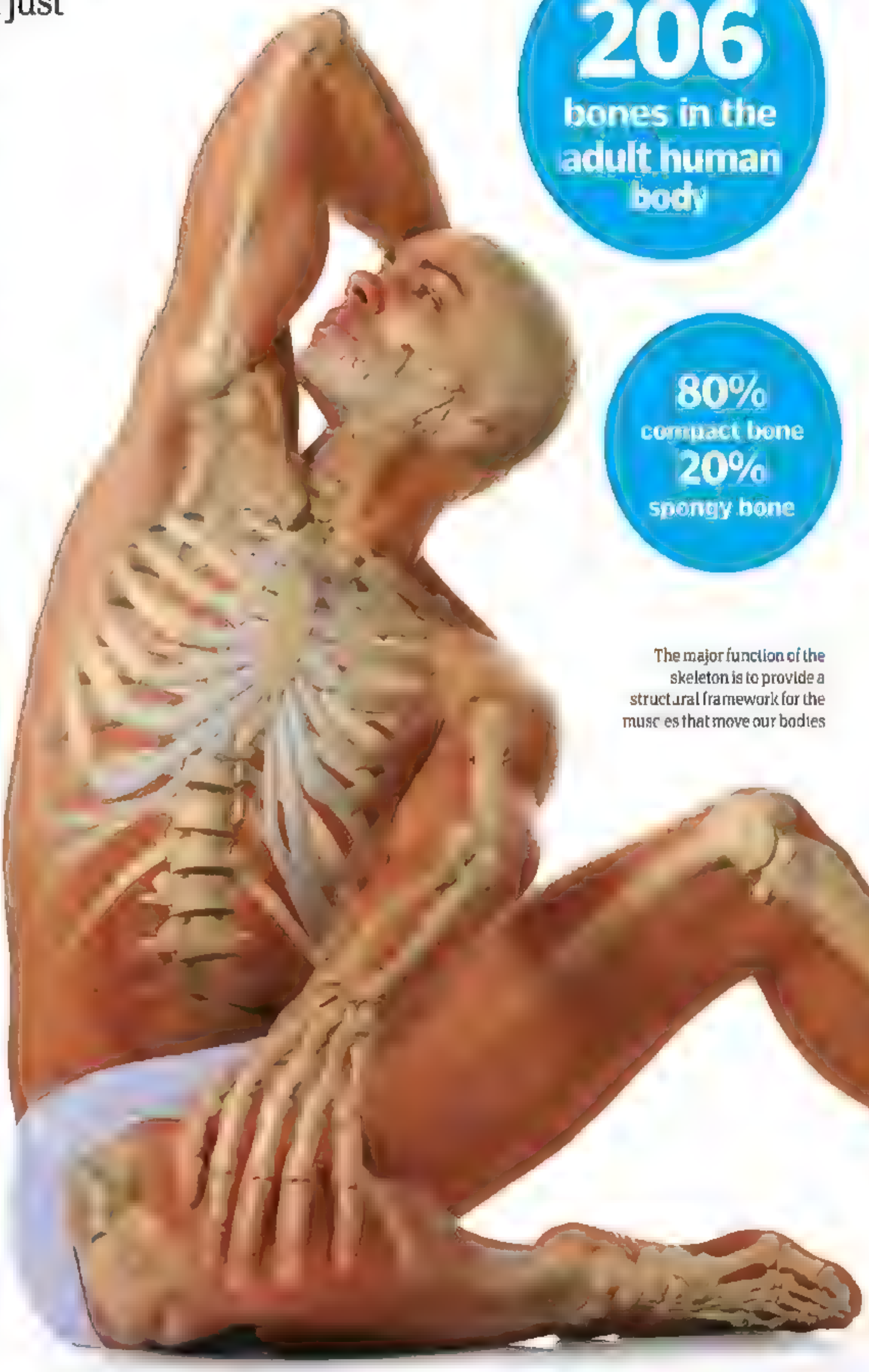
Bone is a composite material, constructed from three basic ingredients: collagen strands, a sugary protein glue and inorganic calcium salts. The collagen fibres are arranged in alternating layers that cross over one another, thereby providing a flexible scaffold, and calcium salts are glued in between for strength and rigidity.

The outside of each bone is composed of plates, or hollow tubes, of dense cortical bone, supported on the inside by a honeycomb network of spongy trabecular bone. This network is slightly flexible and helps to distribute the load, curving the tensile and compressive forces across the ends of the bone, while providing maximum strength.

Spongy bone is also home to the bone marrow, which houses stem cells capable of producing most of the cells of the blood and immune system. They are constantly active, and millions upon millions of new red and white blood cells are produced every minute.

Embedded within the bone matrix are cells known as osteocytes. They do not move, but are capable of detecting stresses inside the bone itself, and can trigger the formation of new bone in a process known as remodelling. The old bone is broken down by large cells, which are called osteoclasts, and new collagen and minerals are deposited by smaller osteoblasts.

Together, the two cell types are able to release and store calcium and phosphorous in the skeleton for use elsewhere in the body. They are under the influence of hormones released by glands in the brain, and when levels of minerals run low in the body, the signals encourage the osteoclasts to begin wearing away at the surface of the bone, releasing minerals into the bloodstream. When mineral levels are high, osteoblasts lay down new bone and this replenishes the store.



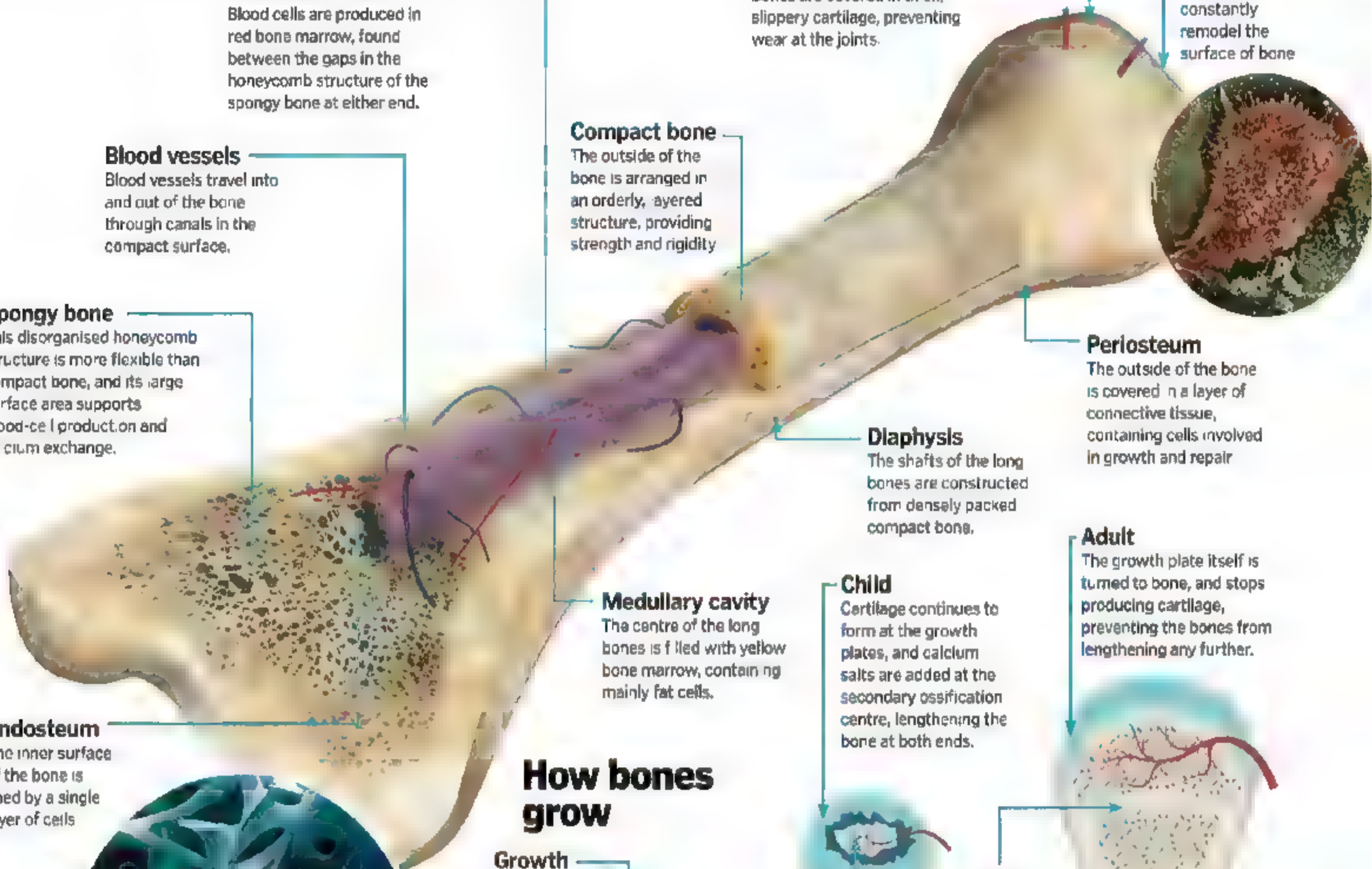
206 bones in the adult human body

80% compact bone **20%** spongy bone

The major function of the skeleton is to provide a structural framework for the muscles that move our bodies

Bone structure

The long bones are formed into tubes, closed at both ends and capped with cartilage



Epiphysis
The ends of the long bones act as shock absorbers, with a casing of tough compact bone supported by a spongy core.

BELOW Ce ls known as osteoclasts constantly remodel the surface of bone

Articular cartilage
The end surfaces of the bones are covered in th ck, slippery cartilage, preventing wear at the joints.

Red bone marrow
Blood cells are produced in red bone marrow, found between the gaps in the honeycomb structure of the spongy bone at either end.

Compact bone
The outside of the bone is arranged in an orderly, ayered structure, providing strength and rigidity

Blood vessels
Blood vessels travel into and out of the bone through canals in the compact surface.

Spongy bone
This disorganised honeycomb structure is more flexible than compact bone, and its large surface area supports blood-ce l product on and ca cium exchange.

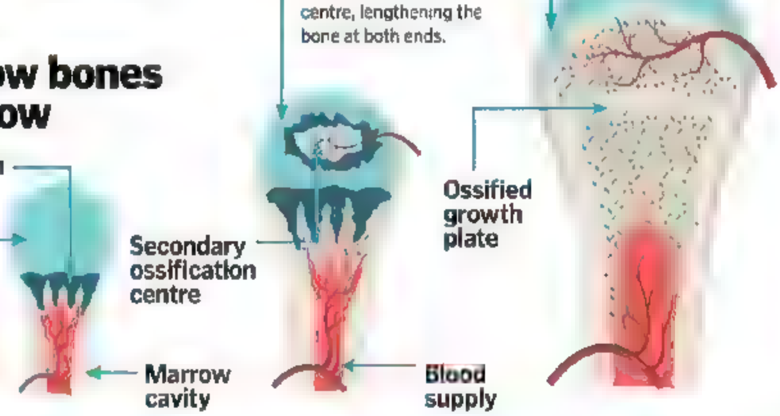
Periosteum
The outside of the bone is covered n a layer of connective tissue, containing cells involved in growth and repair

Diaphysis
The shafts of the long bones are constructed from densely packed compact bone.

Medullary cavity
The centre of the long bones is f lled with yellow bone marrow, contain ng mainly fat cells.

Endosteum
The inner surface of the bone is lined by a single layer of cells

How bones grow



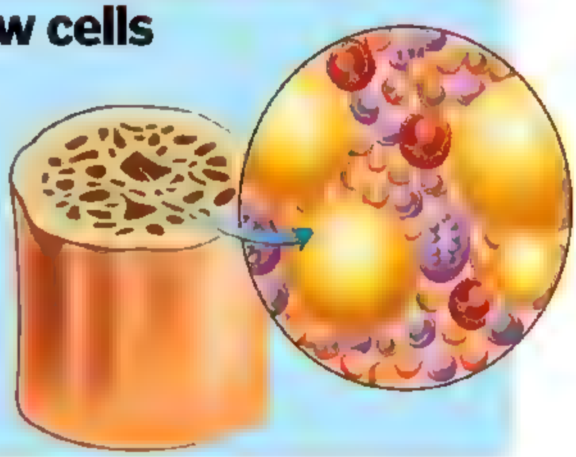
Child
Cartilage continues to form at the growth plates, and calcium salts are added at the secondary ossification centre, lengthening the bone at both ends.

Adult
The growth plate itself is turned to bone, and stops producing cartilage, preventing the bones from lengthening any further.

Newborn
In the womb, most of the skeleton is made of cartilage, but gradually minerals are laid down and it is converted to bone in a process known as ossification.

Bone marrow cells

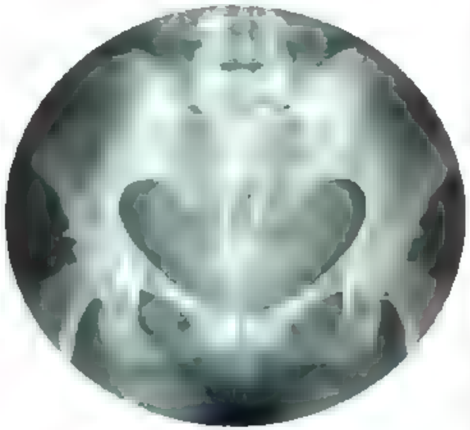
There are two types of bone marrow in the human body, yellow marrow is found in the shafts of the ong bones, like the femur, and red marrow is mainly found in the flat bones, like the ribs. Yellow marrow is mostly made up of large fat cells, whilst red marrow contains stem cel s. These are capable of producing most of the cells of the b ood and immune system and concea ed within the bones are many immature cells n the process of development.



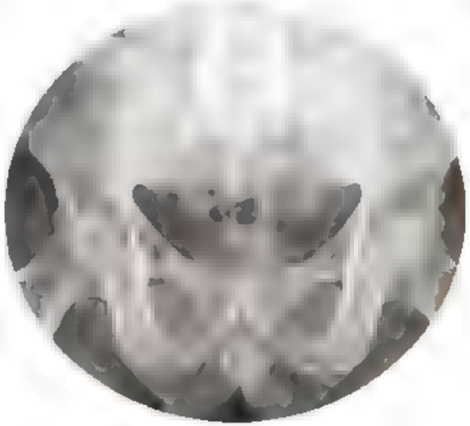
Skeletal system

Get to know the bones in your body with our guide to the human skeleton

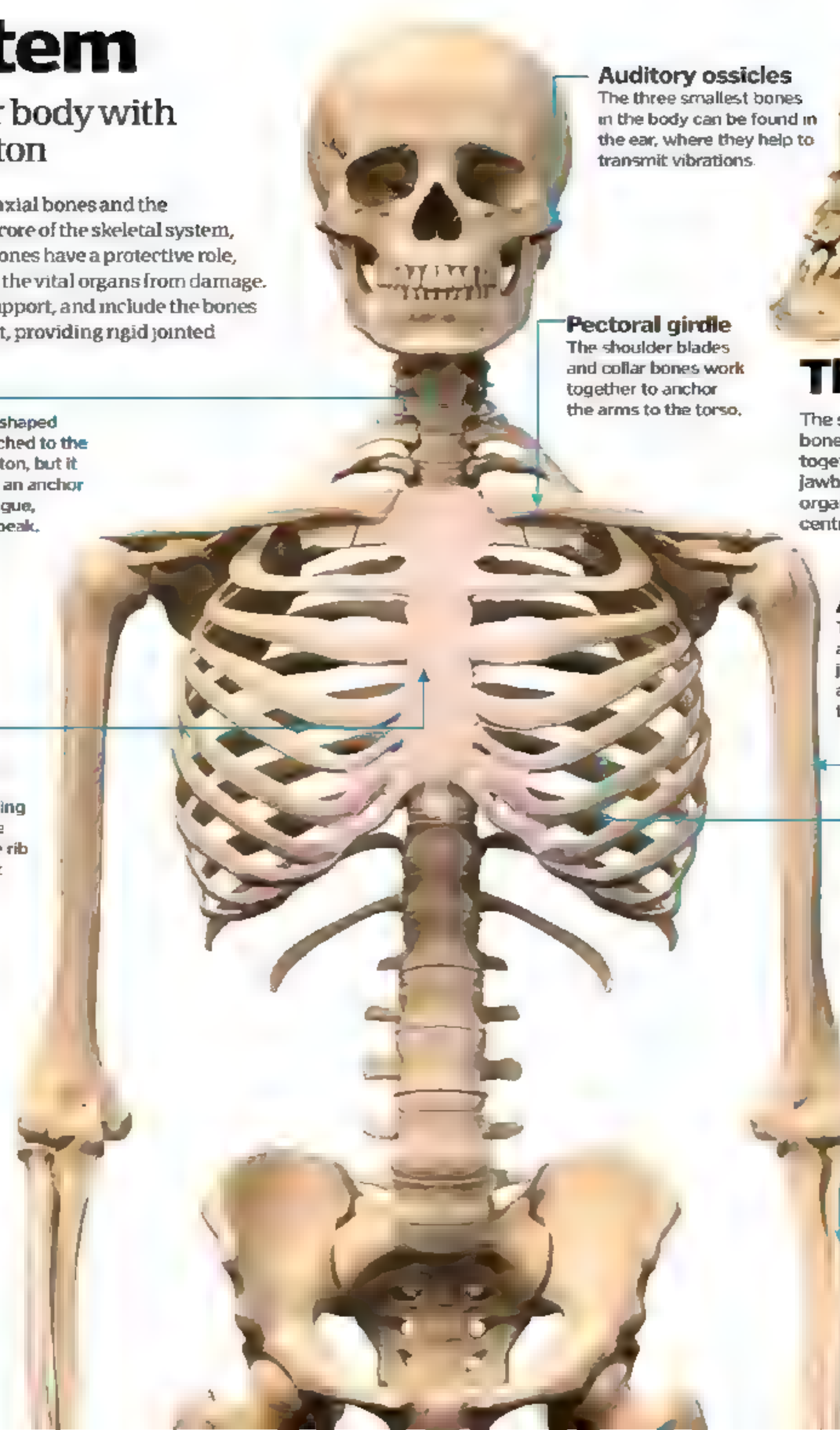
There are two major parts to the human skeleton: the axial bones and the appendicular bones. The axial bones form the central core of the skeletal system, including the skull, spine, rib cage and pelvis. These bones have a protective role, supporting the central nervous system and protecting the vital organs from damage. The appendicular bones are attached to this central support, and include the bones of the arms and legs. Their major function is movement, providing rigid jointed structures onto which the muscles are attached.



ABOVE Females have a larger opening inside the pelvis, aiding childbirth



ABOVE The male pelvis is relatively narrow and the opening is heart-shaped



Hyoid
This horseshoe-shaped bone is not attached to the rest of the skeleton, but it helps to provide an anchor point for the tongue, enabling us to speak.

Sternum
The ribs are anchored to the sternum by cartilage, providing a flexible linkage and allowing the rib cage to contract and expand

Auditory ossicles
The three smallest bones in the body can be found in the ear, where they help to transmit vibrations.

Pectoral girdle
The shoulder blades and collar bones work together to anchor the arms to the torso.

Arm
The humerus makes a ball-and-socket joint at the shoulder, and a hinge joint at the elbow.

Ribs
Most people have 12 pairs of ribs that, together with the spinal column and sternum, form a protective cage around the heart and lungs

Forearm
The two bones of the forearm split the load; the ulna bears weight near the elbow, and the radius bears weight near the wrist

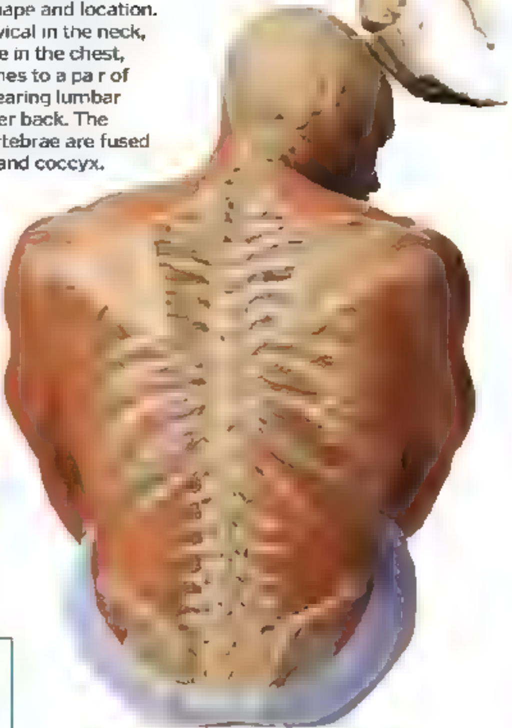
The skull

The skull is constructed out of 22 plates of flat bone, 21 of which are permanently fused together. The other is the mandible, or jawbone. They are made from a thick layer of organised cortical bone, sandwiched around a centre of spongy bone.

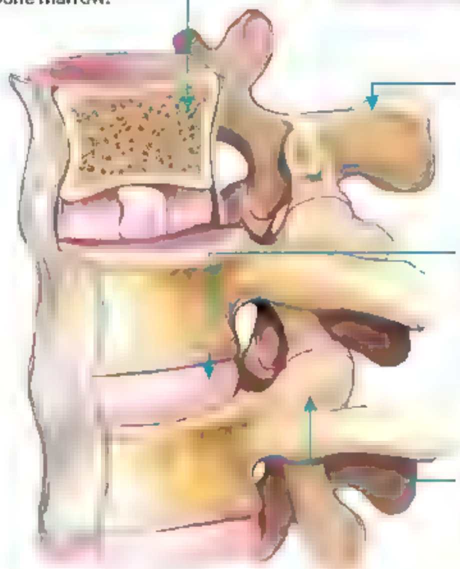
10 years to

The spine

There are 33 vertebrae in the spinal column, divided into categories according to their shape and location. There are seven cervical in the neck, 12 thoracic vertebrae in the chest, each of which attaches to a pa r of ribs, and five load-bearing lumbar vertebrae n the lower back. The remainder of the vertebrae are fused to form the sacrum and coccyx.



33 vertebrae in the spine

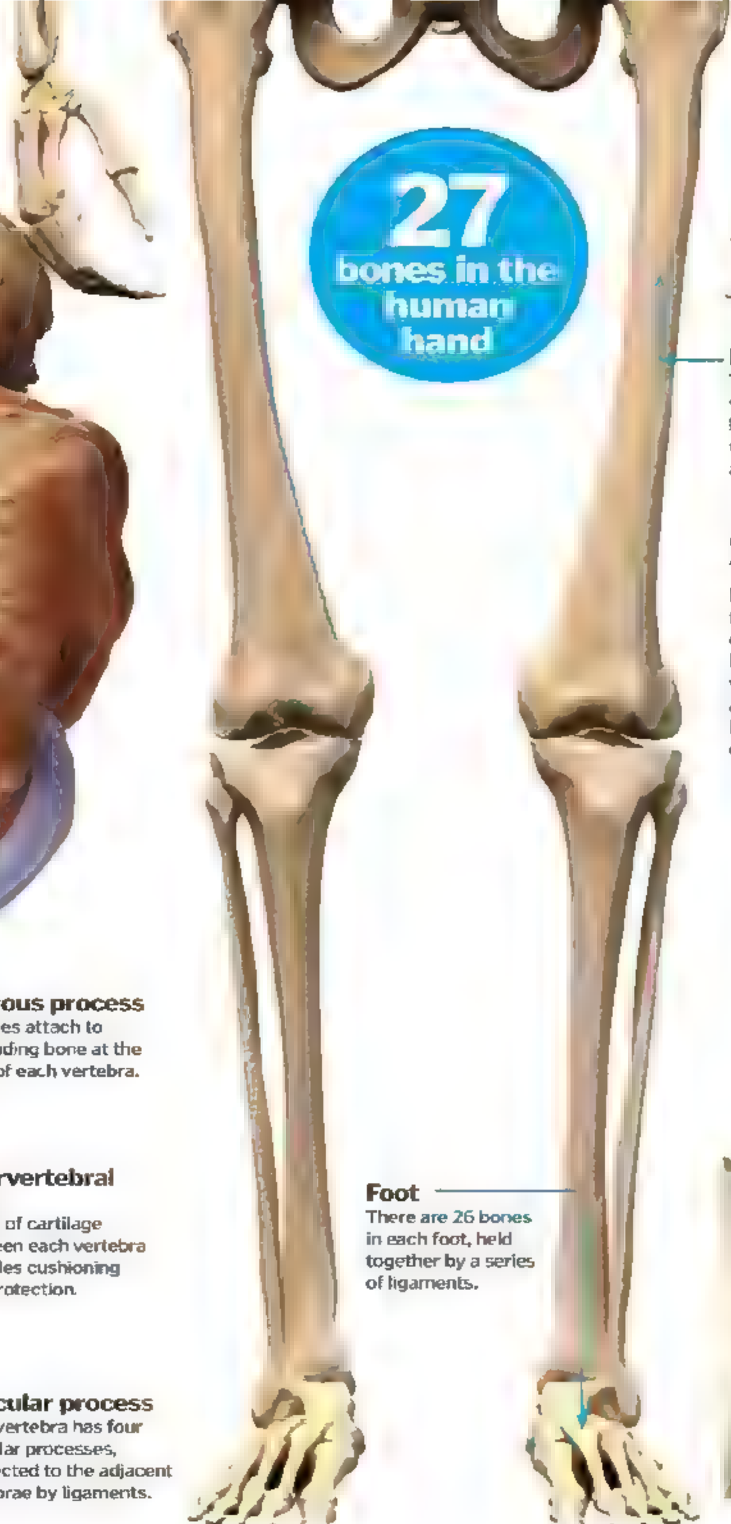


Vertebral body
Each vertebra conta ns a core of spongy bone and red bone marrow.

Spinous process
Muscles attach to protruding bone at the back of each vertebra.

Intervertebral disk
A disk of cartilage between each vertebra provides cushioning and protection.

Articular process
Each vertebra has four articular processes, connected to the adjacent vertebrae by ligaments.



27 bones in the human hand

Wrist, hand and fingers
There are 27 bones in each hand, eight of which make up the wrist.

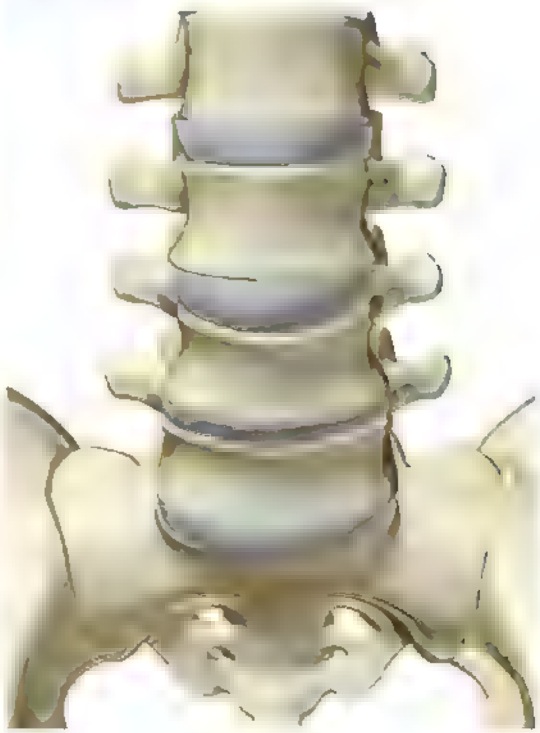
Lower limb
The weight of the body is supported by the femur (thigh bone) and the tibia (shin bone), while the fibula is involved in anchoring the muscles of the foot

Foot
There are 26 bones in each foot, held together by a series of ligaments.

Learn more
Get your own giant 1.3m high poster to help explore every bone in the human skeleton – great for home and schools. Drawn to scale and anatomically detailed by leading medical artist, Joanna Culley. A matching muscle poster is also available, all from www.uAnatomy.com.

Shock absorbers

Between the vertebrae of the spine are disks of a springy tissue known as fibrocartilage, made up of ong chains of collagen and bound together by a gel of sugary proteins, known as glycoproteins These have a strong affinity for water, so as a result, the entire tissue is filled with fluid It acts like suspension, compressing and deforming under load and protecting the bones from the stress of day-to-day impact.



Joints

For individual bones to function together, they must be linked by joints

Some bones, like those in the skull, do not need to move, and are permanently fused together with mineral sutures. These are known as fixed joints and provide maximum stability.

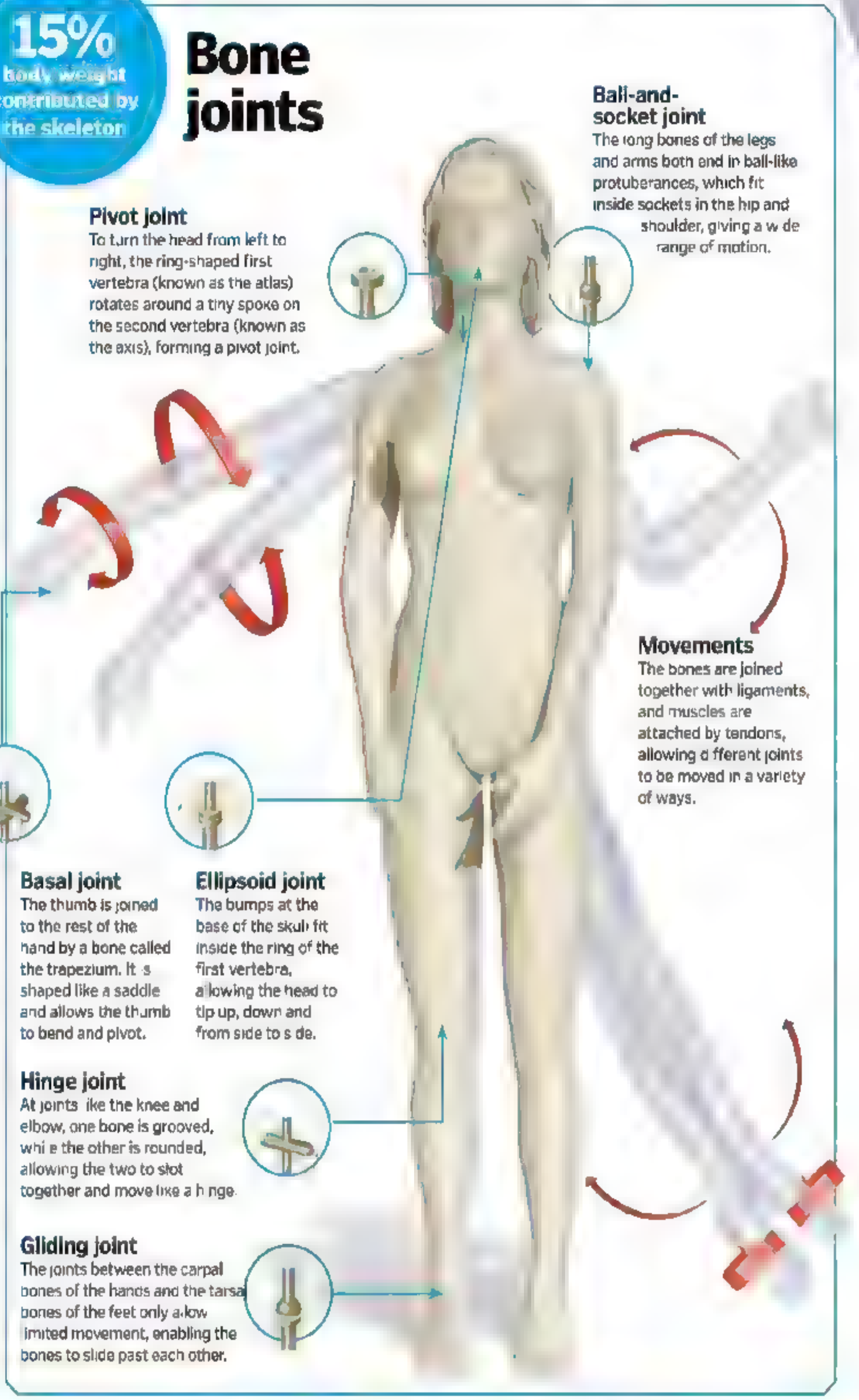
However, most bones need flexible linkages. In some parts of the skeleton, partial flexibility is sufficient, so all that the bones require is a little cushioning to prevent rubbing. The bones are joined by a rigid gel-like tissue known as cartilage, which allows for a small range of compression and stretching. These types of joints are used where the ribs meet the sternum, to provide flexibility when breathing, and between the stacked vertebrae of the spinal column, allowing it to bend and flex without crushing the spinal cord.

Most joints require a larger range of movement. Covering the ends of the bones in cartilage provides shock absorption, but for them to move freely in a socket, the cartilage must be lubricated to make it slippery and wear-proof. At synovial joints, the ends of the two bones are encased in a capsule, covered on the inside by a synovial membrane, which fills the joint with synovial fluid, allowing the bones to slide smoothly past one another.

There are different types of synovial joint, each with a different range of motion. Ball-and-socket joints are used at the shoulder and hip, and provide a wide range of motion, allowing the curved surface at the top end of each limb to slide inside a cartilage covered cup. The knees and elbows have hinge joints, which interlock in one plane, allowing the joint to open and close. For areas that need to be flexible, but do not need to move freely, such as the feet, gliding joints allow the bones to slide small distances without rubbing together.

15% body weight contributed by the skeleton

Bone joints

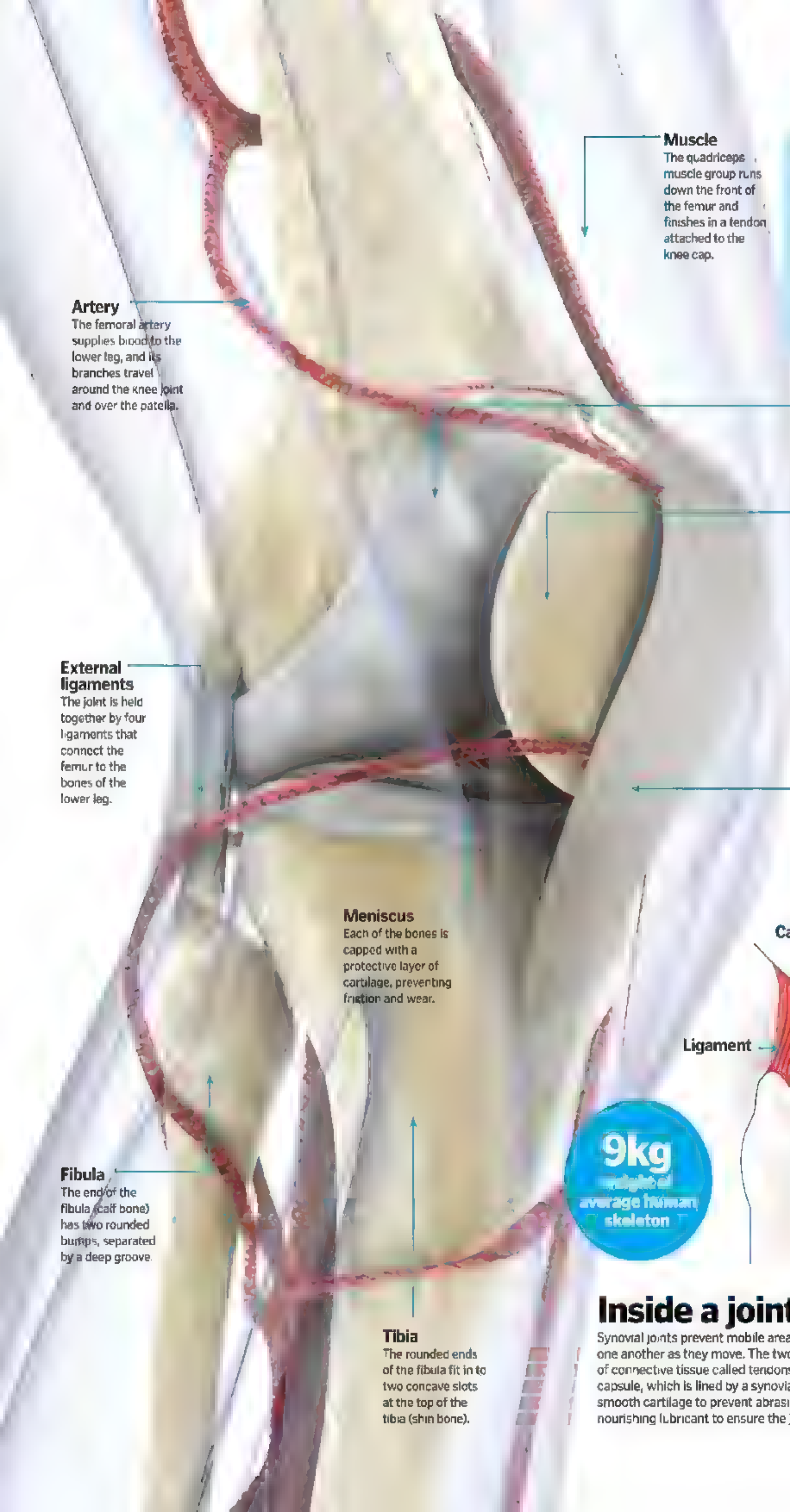


Hypermobility

Mobile

Semimobile

Fixed

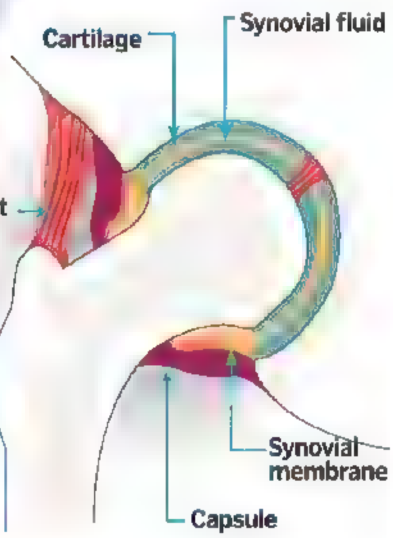


Why our joints crack

The synovial fluid used to lubricate the joints contains dissolved gasses. The fluid is sealed within a capsule, so if the joint is stretched, the capsule also stretches, creating a vacuum as the pressure changes, and pulling the gas out of solution and into a bubble, which pops, producing a cracking sound.

300+ bones in a newborn baby

9kg weight of average human skeleton

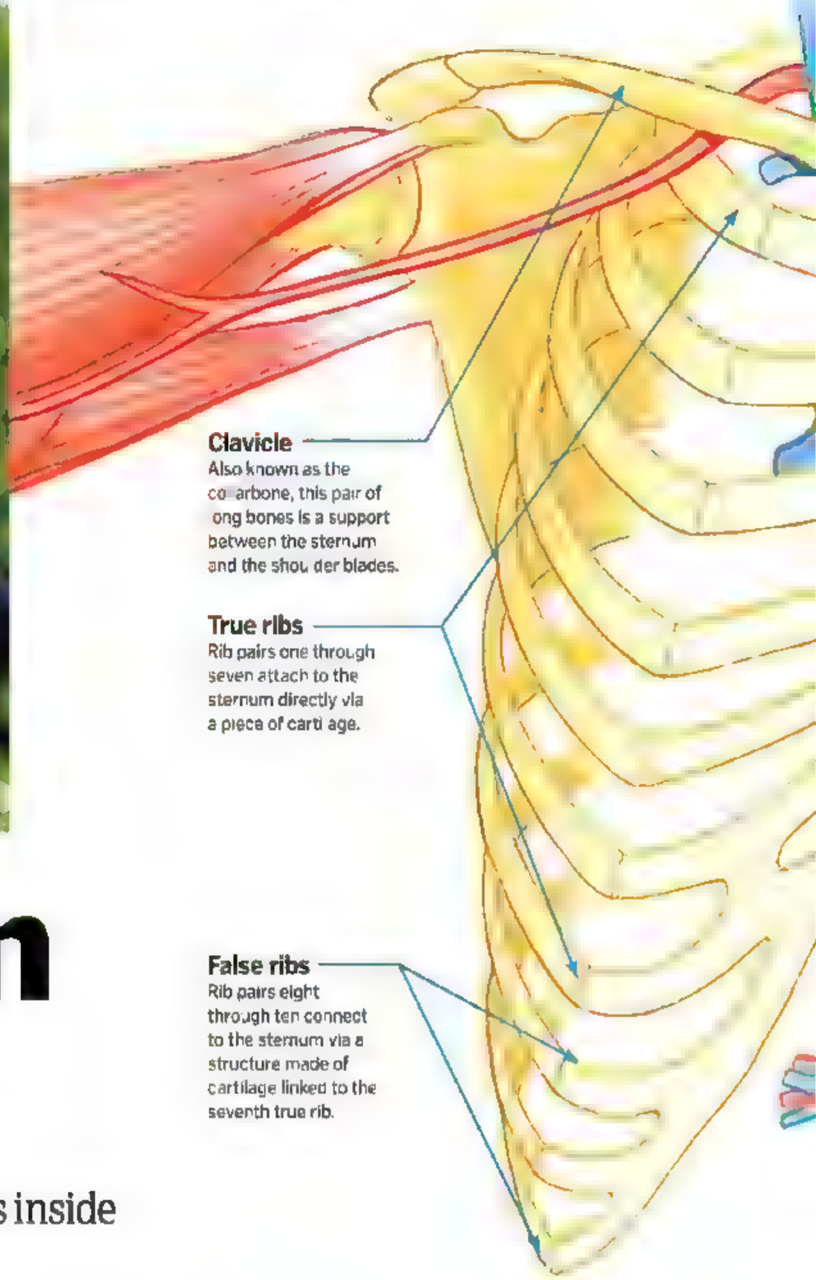


Inside a joint

Synovial joints prevent mobile areas of the skeleton from grinding against one another as they move. The two bones are loosely connected by strips of connective tissue called tendons, and the two ends are encased in a capsule, which is lined by a synovial membrane. The bones are covered in smooth cartilage to prevent abrasion and the membrane produces a nourishing lubricant to ensure the joint moves smoothly.

Inside the thoracic cavity

It may not look like it at first glance, but there are more than two dozen bones that make up the ribcage...



The human ribcage

Ribs are not merely armour for the organs inside our torsos, as we reveal here...

The ribcage – also known as the thoracic cage or thoracic basket – is easily thought of as just a framework protecting your lungs, heart and other major organs. Although that is one key function, the ribcage does so much more. It provides vital support as part of the skeleton and, simply put, breathing wouldn't actually be possible without it.

All of this means that the ribcage has to be flexible. The conical structure isn't just a rigid system of bone – it's actually both bone and cartilage. The ribcage is comprised of 24 ribs that are joined in the back to the 12 vertebrae that make up the middle of the spinal column.

The cartilage portions of the ribs meet in the front at the long, flat three-bone plate called the sternum (breastbone). Or rather, most of them do. Rib pairs one through seven are called 'true ribs' because they attach directly to the sternum. Rib pairs eight through ten attach indirectly through other cartilage structures, so they're referred to as 'false ribs'. The final two pairs – the 'floating ribs' – hang unattached to the sternum.

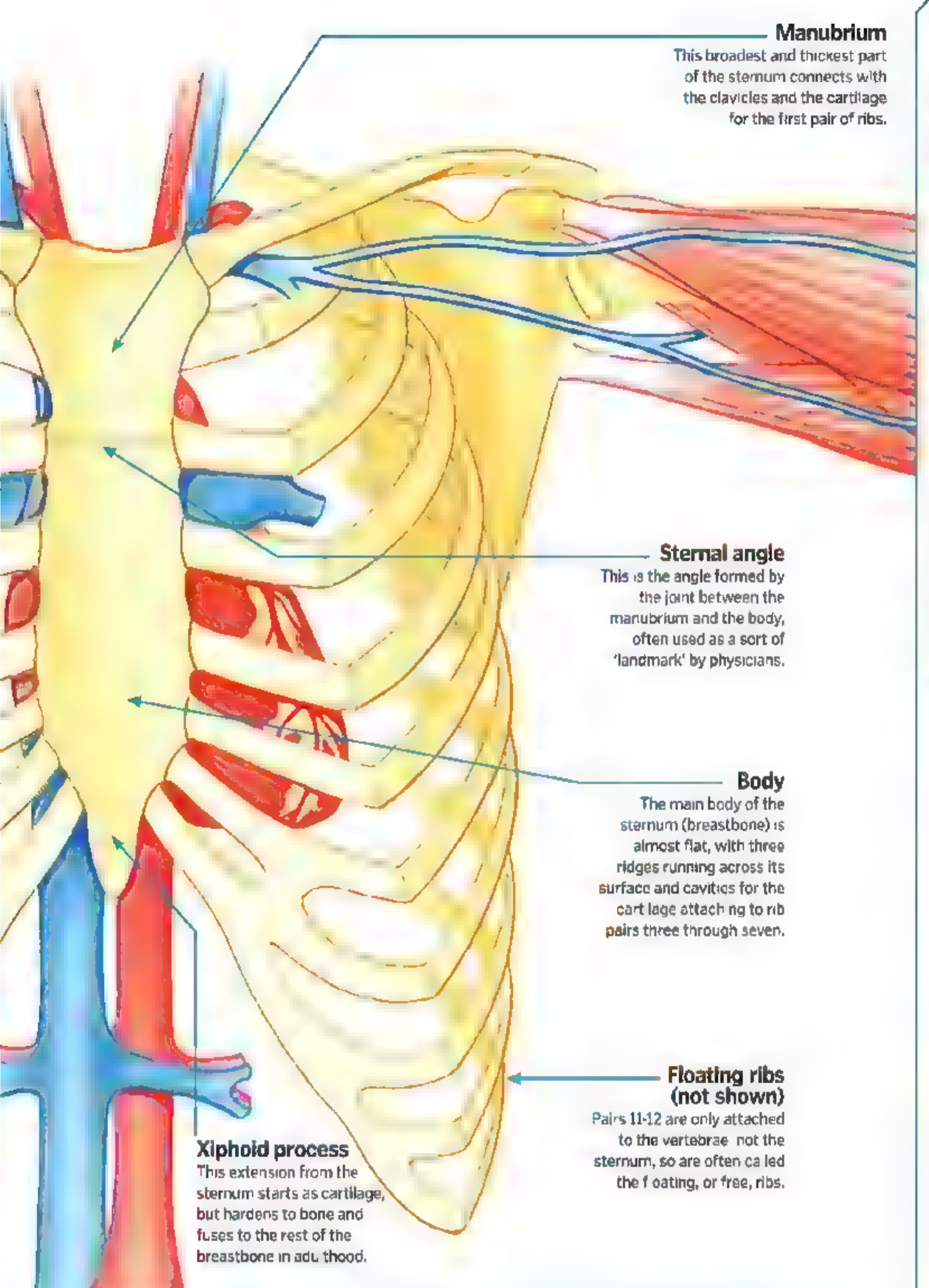
Rib fractures are a common and very painful injury, with the middle ribs the most likely ones to get broken. A fractured rib can also be very dangerous, because a sharp piece could pierce the heart or lungs.

There's also a condition called flail chest, in which several ribs break and then detach from the cage, which can even be fatal. But otherwise there's not much you can do to mend a fractured rib other than keep it stabilised, resting and giving it time to heal

What are hiccups?

Hiccupping – known medic[illegible] synchronous diaphragmatic flutter (SD[illegible] involuntary spasm of the diaphragm that [illegible] happen for a number of reasons. Short-te[illegible] causes include eating or drinking too q[illegible] sudden change in body tem[illegible]

[illegible] that hiccupping in premature babi[illegible] to hiccup much more than full-term b[illegible] due to their underdeveloped lungs. It could be an [illegible]lutionary leftover, since hiccupping in humans [illegible]milar to the way that amphibians gul[illegible] and air into their gills to breath[illegible]

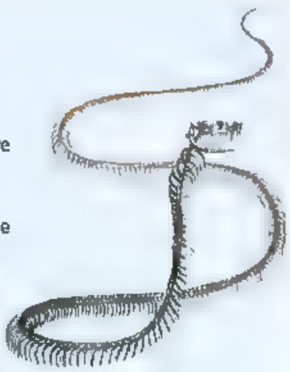


Breathe in, breathe out…

Consciously take in a breath, and think about the fact that there are ten different muscle groups working together to make it happen. The muscles that move the ribcage itself are the intercostal muscles. They are each attached to the ribs and run between them. As you inhale, the external intercostals raise the ribs and sternum so your lungs can expand, while your diaphragm lowers and flattens. The internal intercostals lower the ribcage when you exhale. This forces the lungs to compress and release air (working in tandem with seven other muscles). If you breathe out gently, it's a passive process that doesn't require much ribcage movement.

Ribs in other animals

Most vertebrates (ie animals with backbones) have a ribcage of sorts – however, ribcages can be very different depending on the creature. For example, dogs and cats have 13 pairs of ribs as opposed to our 12. Marsupials have fewer ribs than humans, and some of those are so tiny they aren't much more than knobs of bone sticking out from the vertebrae. Once you get into other vertebrates, the differences are even greater. Birds' ribs overlap one another with hook-like structures called uncinate processes, which add strength. Frogs don't have any ribs, while turtles' eight rib pairs are fused to the shell. A snake's 'ribcage', meanwhile, runs the length of its body and can comprise hundreds of pairs of ribs. Despite the variations in appearance, ribcages all serve the same basic functions for the most part: to provide support and protection to the rest of the body.



The human hand

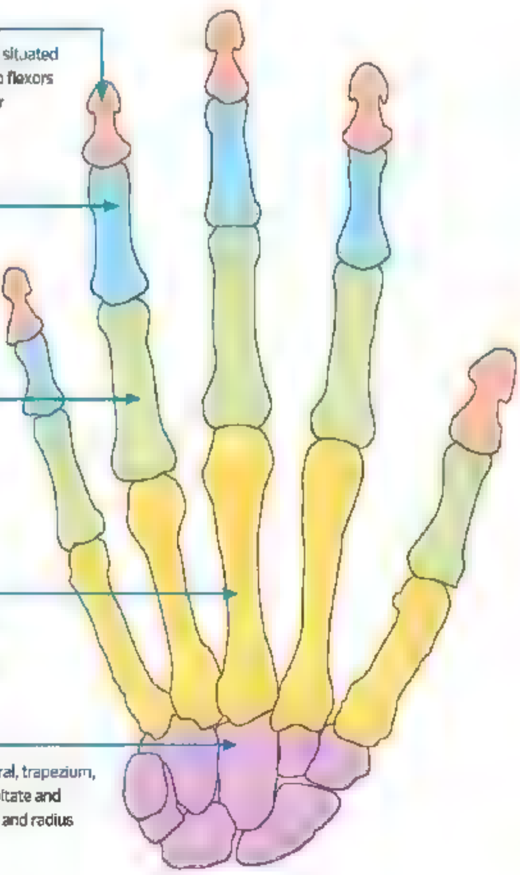
We take our hands for granted, but they are actually quite complex and have been crucial in our evolution

The human hand is an important part of the body that allows individuals to manipulate their surroundings, and gather large amounts of data from their environment. A hand is generally defined as the terminal aspect of the human arm, which consists of prehensile digits, an opposable thumb, and a wrist and palm. Although many other animals have similar structures, only primates and a limited number of other vertebrates can be said to have a 'hand', due to the need for an opposable thumb to be present and the degree of extra articulation that the human hand can achieve. Due to this extra articulation, humans have developed fine motor skills allowing for much increased control in this limb. Consequently we see improved ability to grasp and grip items and development of skills such as writing.

A normal human hand is made up of five digits, the palm and wrist. It consists of 27 bones, tendons, muscles and nerves, with each fingertip containing numerous nerve endings, making the hand a crucial area for gathering information from the surrounding environment using one of man's most crucial five senses: touch. The muscles interact together with tendons to allow fingers to bend, straighten, point and, in the case of the thumb, rotate. However, the hand can often be injured due to the number of ways we use it. One in ten injuries in A&E are hand related, and there are several disorders that can affect the hand development whilst still in the womb, such as polydactyly, where an individual is born with extra digits that are often still in perfect working order.

Bones in the hand

The human hand contains 27 bones, and these are divided up into three distinct groups: the carpals, metacarpals and phalanges. These groups are then broken down into another three different categories: the proximal phalanges, the intermediate phalanges and then the distal phalanges. Eight bones are situated in the wrist and these are collectively called the carpals. The metacarpals, which are situated in the palm of the hand, account for a further five out of the 27 bones. While each finger has three phalanges, the thumb only has two. The intrinsic muscles and tendons control the movement of the digits and hand, and are attached to the extrinsic muscles that extend further up into the arm, flexing the digits.



Distal phalanges
A distal phalange (fingertip) is situated at the end of each finger. Deep flexors attach to this bone to allow for maximum movement.

Intermediate phalanges
This is where the superficial flexors attach via tendons to allow the digit to bend.

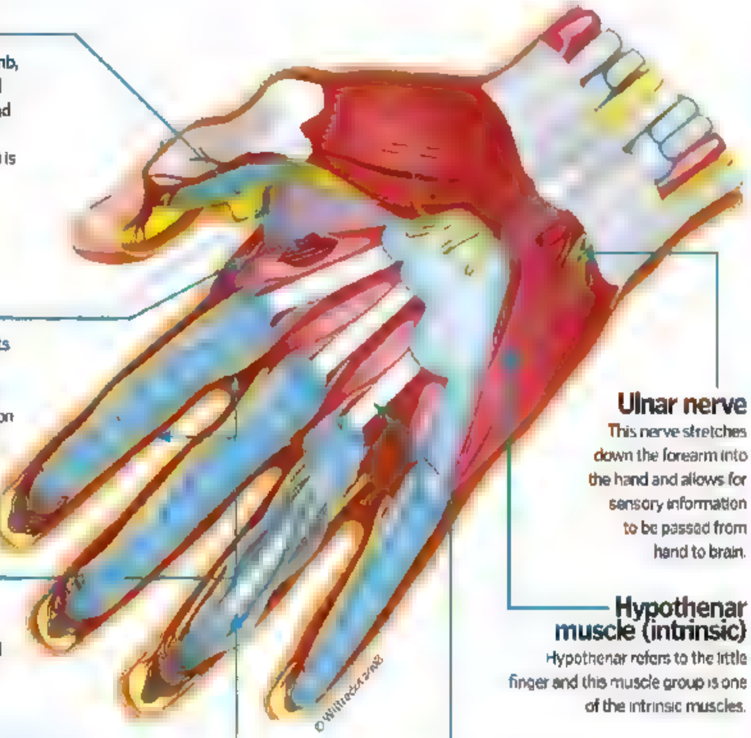
Proximal phalanges
Each finger has three phalanges, and this phalange joins the intermediate to its respective metacarpal.

Metacarpals
These five bones make up the palm, and each one aligns with one of the hand's digits.

Carpals
The carpals (scaphoid, triquetral, trapezium, trapezoid, lunate, hamate, capitate and pisiform) sit between the ulna and radius and the metacarpals.

Muscles and other structures

The movements and articulations of the hand and by the digits are not only controlled by tendons but also two muscle groups situated within the hand and wrist. These are the extrinsic and intrinsic muscle groups, so named as the extrinsics are attached to muscles which extend into the forearm, whereas the intrinsics are situated within the hand and wrist. The flexors and extensors, which make up the extrinsic muscles, use either exclusively tendons to attach to digits they control (flexors) or a more complex mix of tendons and intrinsic muscles to operate (extensors). These muscles will contract in order to cause digit movement, and flexors and extensors work in a pair to complement each to straighten and bend digits. The intrinsic muscles are responsible for aiding all extrinsic muscle action and any other movements in the digits and have three distinct groups; the thenar and hypothenar (referring to the thumb and little finger respectively), the interossei and the lumbrical.



Thenar space
Thenar refers to the thumb, and this space is situated between the first digit and thumb. One of the deep flexors (extrinsic muscle) is located in here.

Interossei muscle (intrinsic)
This interossei muscle sits between metacarpal bones and will unite with tendons to allow extension using extrinsic muscles.

Arteries, veins and nerves
These supply fresh oxygenated blood (and take away deoxygenated blood) to hand muscles.

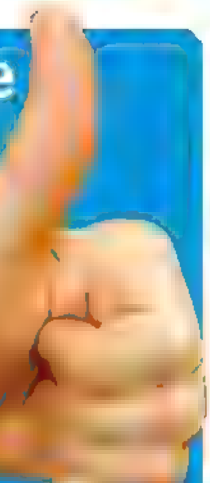
Ulnar nerve
This nerve stretches down the forearm into the hand and allows for sensory information to be passed from hand to brain.

Hypothenar muscle (intrinsic)
Hypothenar refers to the little finger and this muscle group is one of the intrinsic muscles.

Insertion of flexor tendon
This is where the tendon attaches the flexor muscle to the finger bones to allow articulation.

Mid palmar space
Tendons and intrinsic muscles primarily inhabit this space within the hand.

Opposable thumbs



Increased articulation of the thumb has been heralded as one of the key [illegible] human evolut[illegible] it allowed for increased [illegible] control and gri[illegible] and has allowed for tool use in order to develop among human[illegible] [illegible] primates. This has later also facilitated major cultural advances such a[illegible] [illegible]ting. Alongside the four other flexible digits, the opposable thumb makes the human hand one of the most dexterous in the world. A thumb can only be classified as opposable when it can be brought opposite to the other digits.

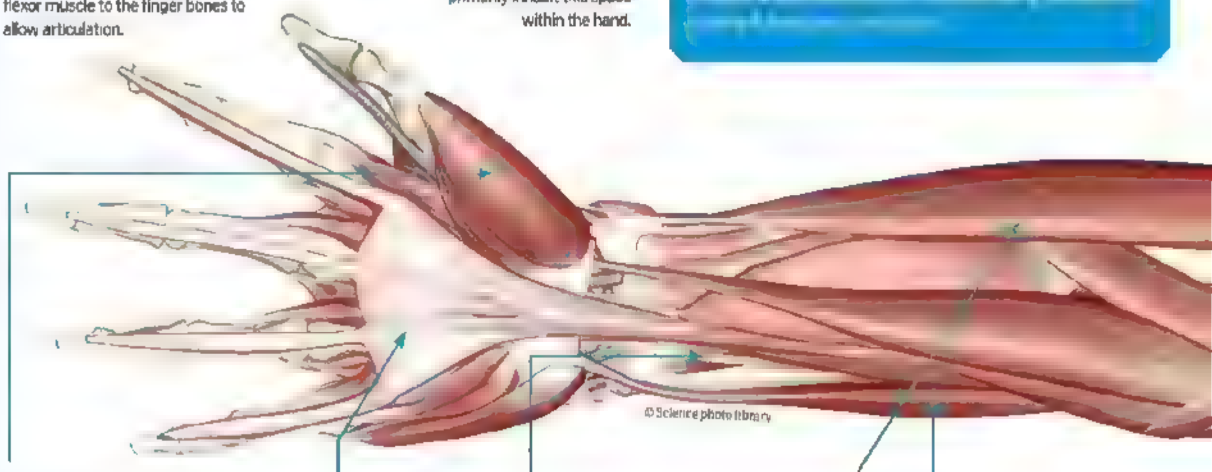
Left-handed or right-handed?

The most common theor[illegible] for why some individuals are left-handed is that of the [illegible] [illegible]aring [illegible] supposes that the left-handed individual was actually one of a set of twins, but that in the early stages [illegible] the other, [illegible]ht-handed, twin died. However, i[illegible] been found that dominance of one hand is directly linked [illegible]th hemisphere dominance in the brain, a[illegible] in many other paired organs.

Individuals who somehow damage their dominant hand for extended periods of time can [illegible]

Forearm muscles

Extrinsic muscles are so called because they are primarily situated outside the hand, the body of the muscles situated along the underside or front of the forearm. This body of muscles actually breaks down into two quite distinct groups: the flexors and the extensors. The flexors run alongside the underside of the arm and are responsible for allowing the bending of the individual digits, whereas the extensor muscles' main purpose is the reverse this action, to straighten the digits. There are both deep and superficial flexors and extensors, and which are used at any one time depends on the digit to be moved.



Tendons and intrinsics
These attach the flexor muscles to the phalanges, and facilitate bending. Tendons also interact with the intrinsics and extensors in the wrist, palm and forearm to straighten the digits.

Thenars
The intrinsic group of muscles is used to flex the thumb and control its sideways movement.

Superficial flexors
The other flexor that acts on the digits is the superior flexor, which attaches to the intermediate phalanges.

Deep flexors
The digits have two extrinsic flexors that allow them to bend, the deep flexor and the superficial. The deep flexor attaches to the distal phalanges.

Extensors
Extensors on the back of the forearm straighten the digits. Divided into six sections, their connection to the digits is complex.

How do your feet work?

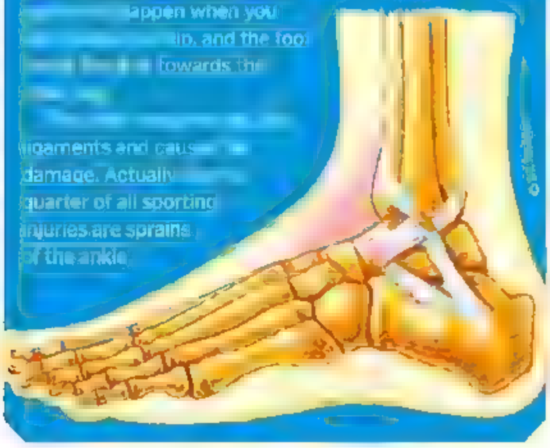
Feet are immensely complex structures, yet we put huge amounts of pressure on them every day. How do they cope?

The human foot and ankle is crucial for locomotion and is one of the most complex structures of the human body. This intricate structure is made up of no less than 26 bones, 20 muscles, 33 joints – although only 20 are articulated – as well as numerous tendons and ligaments. Tendons connect the muscles to the bones and facilitate movement of the foot, while ligaments hold the tendons in place and help the foot move up and down to initiate walking. Arches in the foot are formed by ligaments, muscles and foot bones and help to distribute weight, as well as making it easier for the foot to operate efficiently when walking and running. It is due to the unique structure of the foot and the way it distributes pressure throughout all aspects that it can withstand constant pressure throughout the day. One of the other crucial functions of the foot is to aid balance, and toes are a crucial aspect of this. The big toe in particular helps in this area, as we can grip the ground with it if we feel we are losing balance.

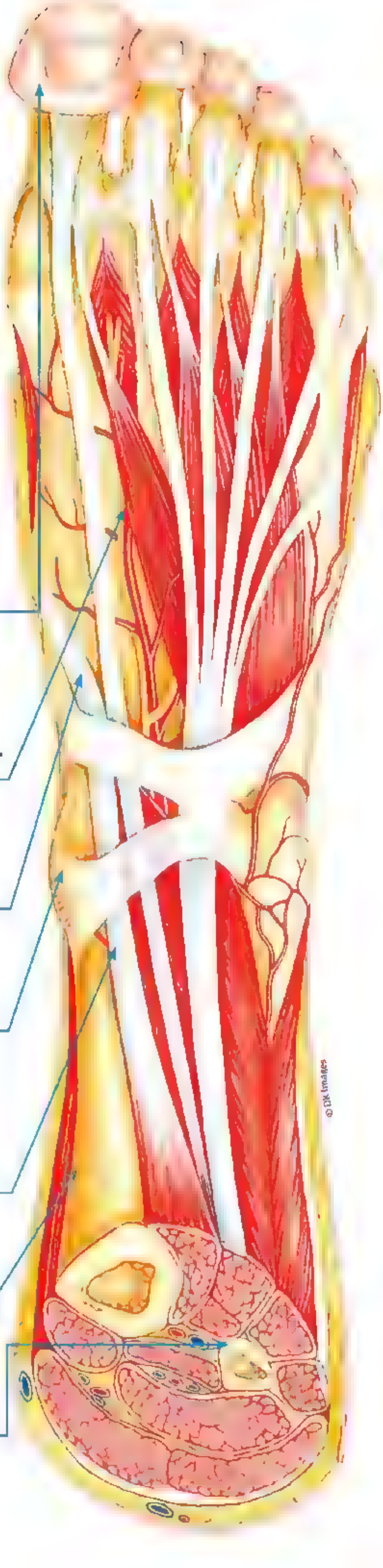
The skin, nerves and blood vessels make up the rest of the foot, helping to hold the shape and also supplying it with all the necessary minerals, oxygen and energy to help keep it moving easily and constantly.

What happens when you sprain your ankle?

A sprained ankle is the most common type of soft [illegible] injury. The severity of the sprain can depend on [illegible] you sprained the ankle, and a minor sprain will generally consist of a stretched or only partially torn ligament. However, more severe sprains can cause the ligament to tear completely, or even force a piece of [illegible] to break off. Generally a [illegible] happen when you [illegible] and the foot [illegible] towards the [illegible] ligaments and cause [illegible] damage. Actually [illegible] quarter of all sporting injuries are sprains of the ankle.



The structure of the foot and how the elements work together



Toes
Terminal aspects of the foot that aid balance by grasping onto the ground. They are the equivalent of fingers in the foot structure.

Muscles – including the extensor digitorum brevis muscle
Muscles within the foot help the foot lift and articulate as necessary. The extensor digitorum brevis muscle sits on the top of the foot, and helps flex digits two-four on the foot.

Blood vessels
These supply blood to the foot, facilitating muscle operation by supplying energy and oxygen and removing deoxygenated blood.

Ligaments
Ligaments support the tendons and help to form the arches of the foot, spreading weight across it.

Tendons (extensor digitorum longus, among others)
Fibrous bands of tissue which connect muscles to bones. They can withstand a lot of tension and link various aspects of the foot, facilitating movement.

Tibia
The larger and stronger of the lower leg bones, this links the knee and the ankle bones of the foot.

Fibula
This bone sits alongside the tibia, also linking the knee and the ankle.

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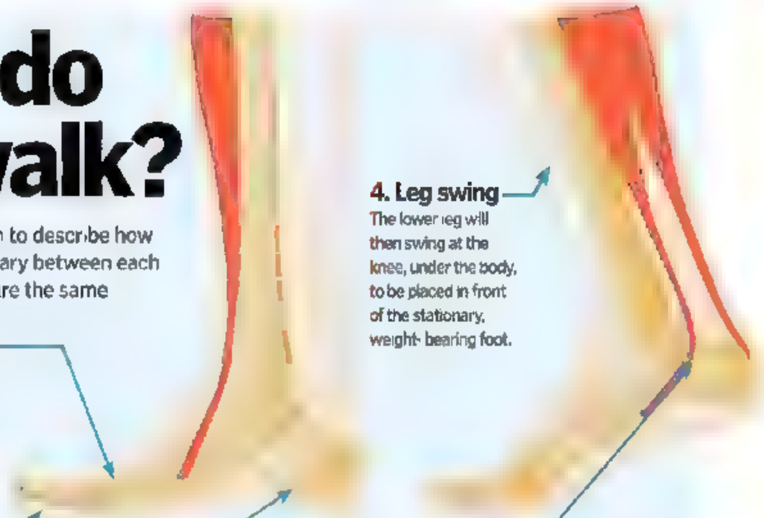
The structure of the foot enables us to stay balanced

How do we walk?

'Human gait' is the term to describe how we walk. This gait will vary between each person, but the basics are the same



2. Weight transfer
The weight will transfer fully to the foot still in contact with the ground, normally with a slight leaning movement of the body.

4. Leg swing
The lower leg will then swing at the knee, under the body, to be placed in front of the stationary, weight-bearing foot.

3. Foot lift
After weight has transferred and the individual feels balanced, the ball of the first foot will then lift off the ground, raising the thigh.

5. Heel placement
The heel will normally be the part of the foot that's placed first, and weight will start to transfer back onto this foot as it hits the ground.

1. Heel lift
The first step of walking is for the foot to be lifted off the ground. The knee will raise and the calf muscle and Achilles tendon, situated on the back of the leg, will contract to allow the heel to lift off the ground.

6. Repeat process
The process is then repeated with the other foot. During normal walking or running, one foot will start to lift as the other starts to come into contact with the ground.

Bones of the foot

A baby is born with 22 out of a total 26 bones in each foot

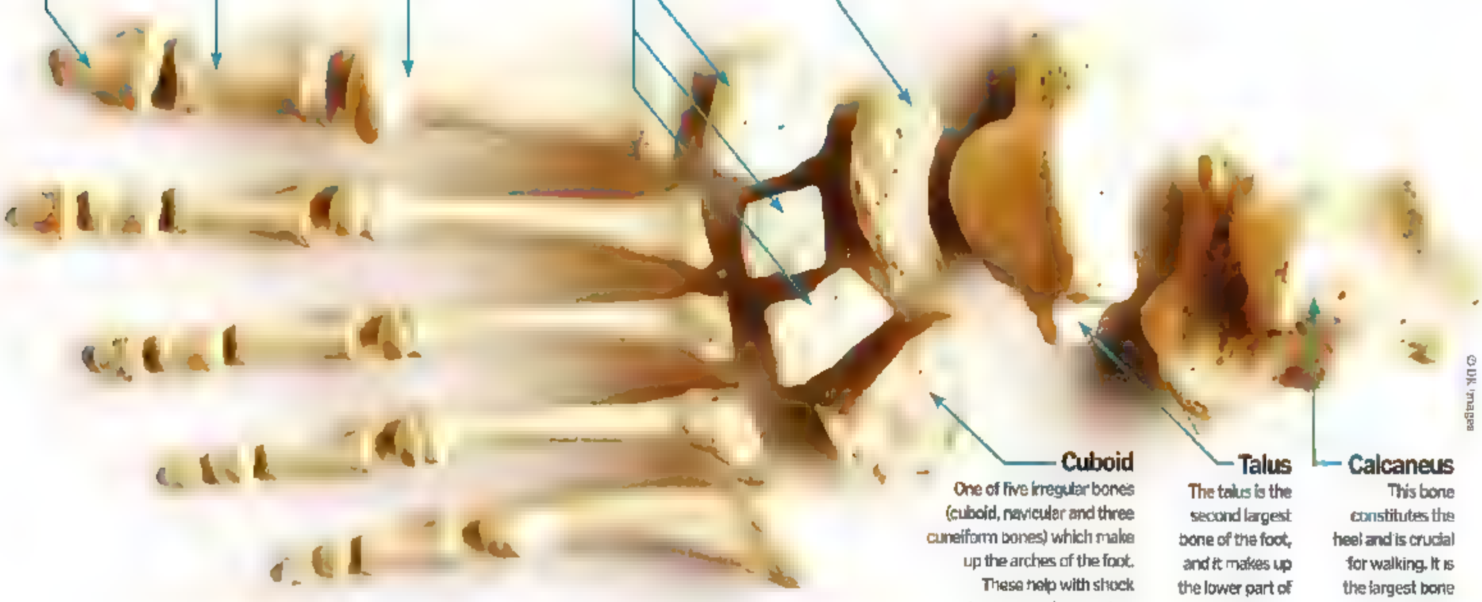
Distal phalanges
The bones which sit at the far end of the foot and make up the tips of the toes.

Proximal phalanges
These bones link the metatarsals and the distal phalanges and stretch from the base of the toes.

Metatarsals
The five, long bones that are the metatarsals are located between the tarsal bones and the phalanges. These are the equivalent of the metacarpals in the hand.

Cuneiforms bones (three)
Three bones that fuse together during bone development and sit between the metatarsals and the talus.

Navicular
This bone, which is so named due to its resemblance to a boat, articulates with the three cuneiform bones.



Cuboid
One of five irregular bones (cuboid, navicular and three cuneiform bones) which make up the arches of the foot. These help with shock absorption in locomotion.

Talus
The talus is the second largest bone of the foot, and it makes up the lower part of the ankle joint.

Calcaneus
This bone constitutes the heel and is crucial for walking. It is the largest bone in the foot.

How do muscles work?

Muscles are essential for us to operate on a daily basis, but how are they structured and how do they keep us moving

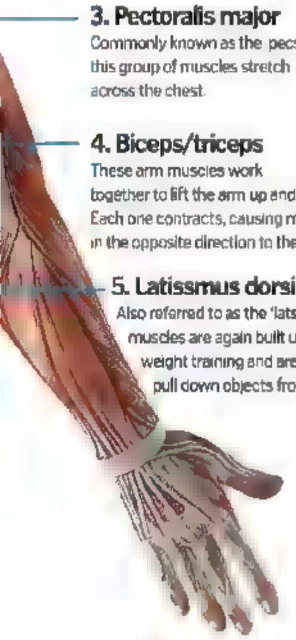
A muscle is a group of tissue fibres that contract and release to control movements within the body. We have three different types of muscles in our bodies – smooth muscle, cardiac muscle and skeletal muscle.

Skeletal muscle, also known as striated muscle, is what we would commonly perceive as muscle, this being external muscles that are attached to the skeleton, such as biceps and deltoids. These muscles are connected to the skeleton with tendons. Cardiac muscle concerns the heart, which is crucial as it pumps blood around the body, supplying oxygen and ultimately energy to muscles, which allows them to operate. Smooth muscle, which is normally sheet muscle, is primarily involved in muscle contractions such as bladder control and oesophagus movements. These are often referred to as involuntary as we have little or no control over these muscles' actions.

Muscles control most functions within our bodies; release of waste products, breathing, seeing, eating and movement to name but a few. Actual muscle structure is quite complex, and each muscle is made up of numerous fibres which work together to give the muscle strength. Muscles increase in effectiveness and strength through exercise and growth and the main way this occurs is through small damage caused by each repetition of a muscle movement, which the body then automatically repairs and improves.

More than 640 muscles are actually present across your entire body working to enable your limbs to work, control bodily functions and shape the body as a whole.

> *"More than 300 individual muscles are present across your body to enable your limbs to work"*



1. Deltoids
These muscles stretch across the shoulders and aid lifting.

2. Trapezius
Large, superficial muscle at the back of the neck and the upper part of the thorax, or chest.

3. Pectoralis major
Commonly known as the 'pecs', this group of muscles stretch across the chest.

4. Biceps/triceps
These arm muscles work together to lift the arm up and down. Each one contracts, causing movement in the opposite direction to the other.

5. Latissmus dorsi
Also referred to as the 'lats', these muscles are again built up during weight training and are used to pull down objects from above.

What affects our muscle strength?

How strong we are is a [illegible]

[illegible] strength refers to the amount of force that [illegible] capacity, in one contraction. Size and structure [illegible] the muscle is important for muscle strength, with strength being measured in several [illegible] Consequently, it is hard to definitively state which muscle is actually strongest.

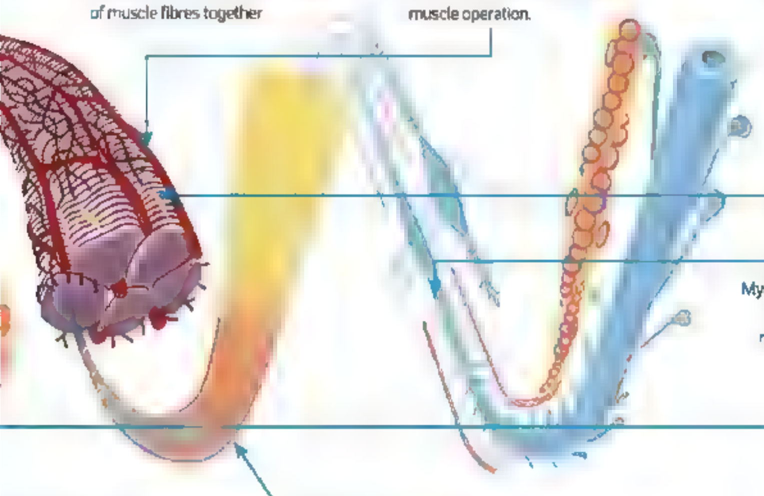
[illegible] have two types of muscle fibre – one that supports long, consta[illegible]sage exerting low level of pressure, and one that suppor[illegible] brief, high level of force. The latter i[illegible]ctivity and these fi[illegible] respond better to muscle building [illegible]enetics can affect muscle strength, as can usage, diet and exercise regimes. Contractions of mu[illegible] cause injuries in the muscle fibres and it is the healing of these that actual[illegible] strength as the injuries are repaired and ove[illegible] strengthen the m[illegible]

> *"Tendons attach muscles such as biceps to bones, allowing muscles to move elements of our body"*

What are muscles made up of?

Muscles are made up of numerous cylindrical fibres, which work together to contract and control parts of the body. Muscle fibres are bound together by the perimysium into small bundles, which are then grouped together by the epimysium to form the actual muscle.

Blood vessels and nerves also run through the connective tissue to give energy to the muscle and allow feedback to be sent to the brain. Tendons attach muscles such as biceps and triceps to bones, allowing muscles to move elements of our body as we wish.



Epimysium
The external layer that covers the muscle overall and keeps the bundles of muscle fibres together.

Blood vessel
This provides oxygen and allows the muscle to access energy for muscle operation.

Perimysium
This layer groups together muscle fibres within the muscle.

Filaments
Myofibrils are constructed of filaments, which are made up of the proteins actin and myosin.

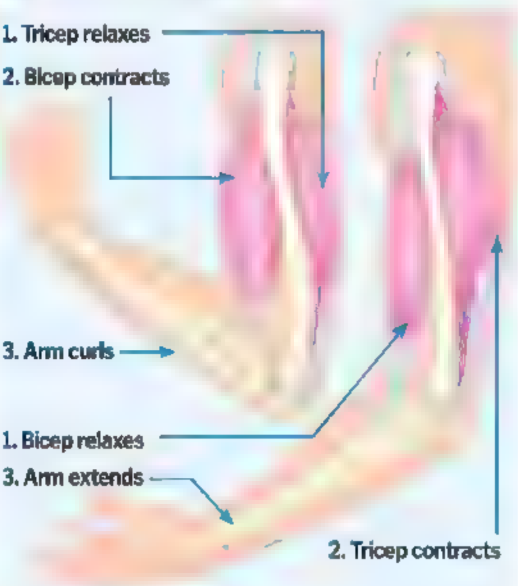
Endomysium
This layer surrounds each singular muscle fibre and keeps the myofibril filaments grouped together.

Tendon
These attach muscle to bones, which in turn enables the muscles to move parts of the body around (off image).

Myofibril
Located within the single muscle fibres, myofibrils are bundles of actomyosin filaments. They are crucial for contraction.

How does the arm flex?

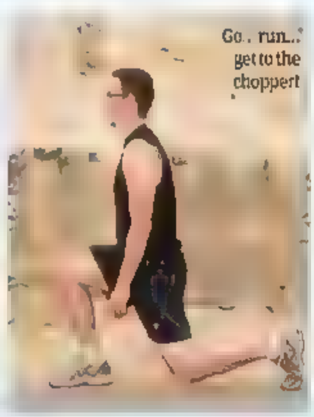
Biceps and triceps are a pair of muscles that work together to move the arm up and down. As the bicep contracts, the triceps will relax and stretch out and consequently the arm will move upwards. When the arm needs to move down, the opposite will occur – with the triceps contracting and the bicep relaxing and being forcibly stretched out by the triceps. The bicep is so named a flexor as it bends a joint, and triceps would be the extensor as it straightens the joint out. Neither of these muscles can push themselves straight, they depend on the other to oppose their movements and stretch them out. Many muscles therefore work in pairs, so-called antagonistic muscles.



What is a pulled muscle, and how does it happen?

They hurt like crazy so here's why it's important to warm up

A pulled muscle is a tear in muscle fibres. Sudden movements commonly cause pulled muscles, and when an individual has not warmed up appropriately before exercise or is unfit, a tear can occur as the muscle is not prepared for usage. The most common muscle to be pulled is the hamstring, which stretches from the buttock to the knee. A pulled muscle may result in swelling and the pain can last for several days before the fibres can repair themselves. To prevent pulling muscles, warming up is advised before doing any kind of physical exertion.



Go... run... get to the chopper!

Anatomy of the neck

Explore one of the most complex and functional areas of the human body

The human neck is a perfect blend of form and function. It has several specific tasks (eg making it possible to turn our heads to see), while serving as a conduit for other vital activities (eg connecting the mouth to the lungs).

The anatomical design of the neck would impress modern engineers. The flexibility of the cervical spine allows your head to rotate, flex and tilt many thousands of times a day.

The muscles and bones provide the strength and flexibility required, however the really impressive design comes with the trachea, oesophagus, spinal cord, myriad nerves and the vital blood vessels. These structures must all find space and function perfectly at the same time. They must also be able to maintain their shape while the neck moves.

These structures are all highly adapted to achieve their aims. The trachea is protected by a ring of strong cartilage so it doesn't collapse, while allowing enough flexibility to move when stretched. Above this, the larynx lets air move over the vocal cords so we can speak. Farther back, the oesophagus is a muscular tube which food and drink pass through en route to the stomach. Within the supporting bones of the neck sits the spinal cord, which transmits the vital nerves allowing us to move and feel. The carotid arteries and jugular veins, meanwhile, constantly carry blood to and from the brain.

How does the head connect to the neck?

They are connected at the bottom of the skull and at the top of the spinal column. The first vertebra is called the atlas and the second is called the axis. Together these form a special pivot joint that grants far more movement than other vertebrae. The axis contains a bony projection upwards, upon which the atlas rotates, allowing the head to turn. The skull sits on top of slightly flattened areas of the atlas, providing a safe platform for it to stabilise on, and allowing for nodding motions. These bony connections are reinforced with strong muscles, adding further stability. Don't forget that this amazing anatomical design still allows the vital spinal cord to pass out of the brain. The cord sits in the middle of the bony vertebrae, where it is protected from bumps and knocks. It sends out nerves at every level (starting right from the top) which actually control over most of the body.

Get it in the neck

We show the major features that are packed into this junction between the head and torso

Sympathetic trunk
These special nerves run alongside the spinal cord, and control sweating, heart rate and breathing, among other vital functions.

Cartilage
This tough tissue protects the delicate airways behind, including the larynx.

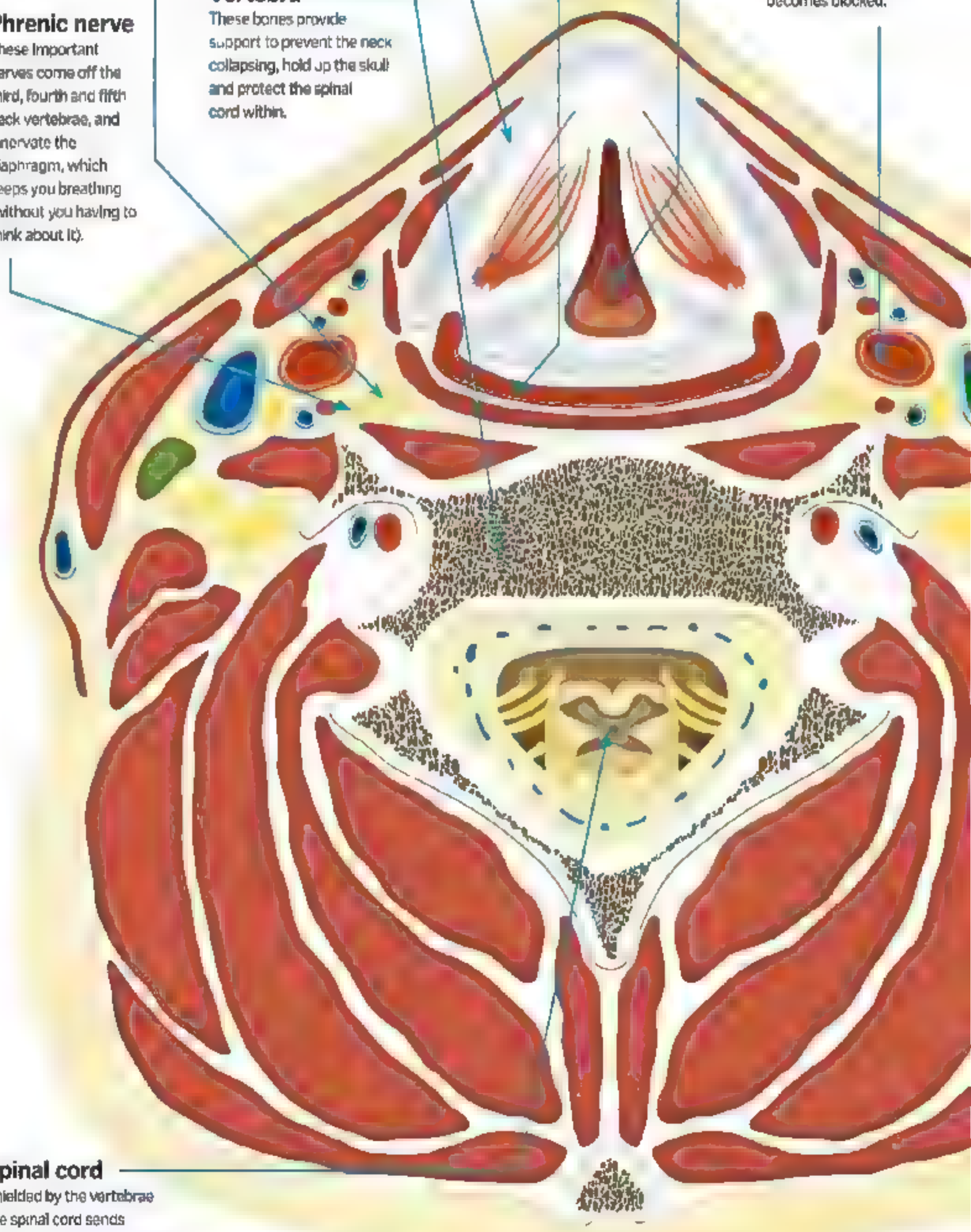
Oesophagus
This pipe connects the mouth to the stomach, and is collapsed until you swallow something, when its muscular walls stretch.

Larynx
This serves two main functions, to connect the mouth to the trachea, and to generate your voice.

Carotid artery
These arteries transmit oxygenated blood from the heart to the brain. There are two of them (right and left), in case one becomes blocked.

Vertebra
These bones provide support to prevent the neck collapsing, hold up the skull and protect the spinal cord within.

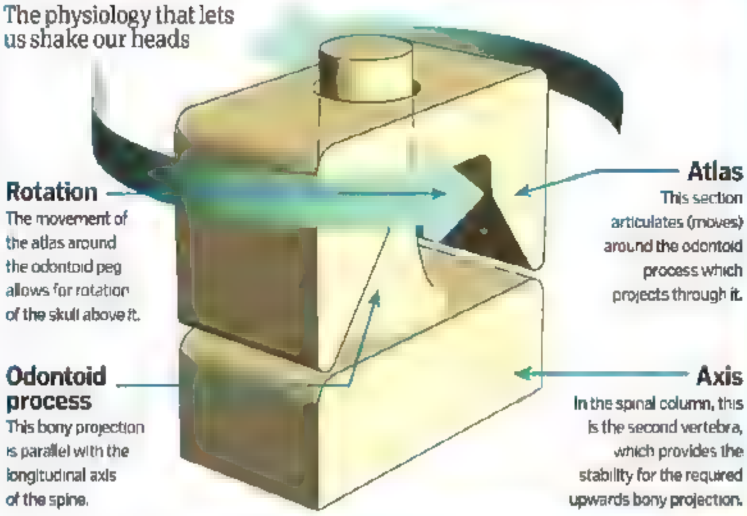
Phrenic nerve
These important nerves come off the third, fourth and fifth neck vertebrae, and innervate the diaphragm, which keeps you breathing (without you having to think about it).



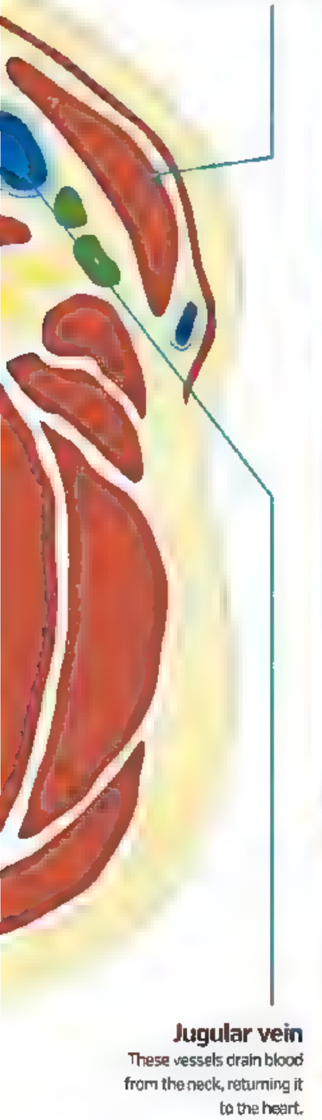
Spinal cord
Shielded by the vertebrae the spinal cord sends motor signals down nerves and receives sensory information from all around the body.

Just say no…

The physiology that lets us shake our heads



The neck in context



Under the skin

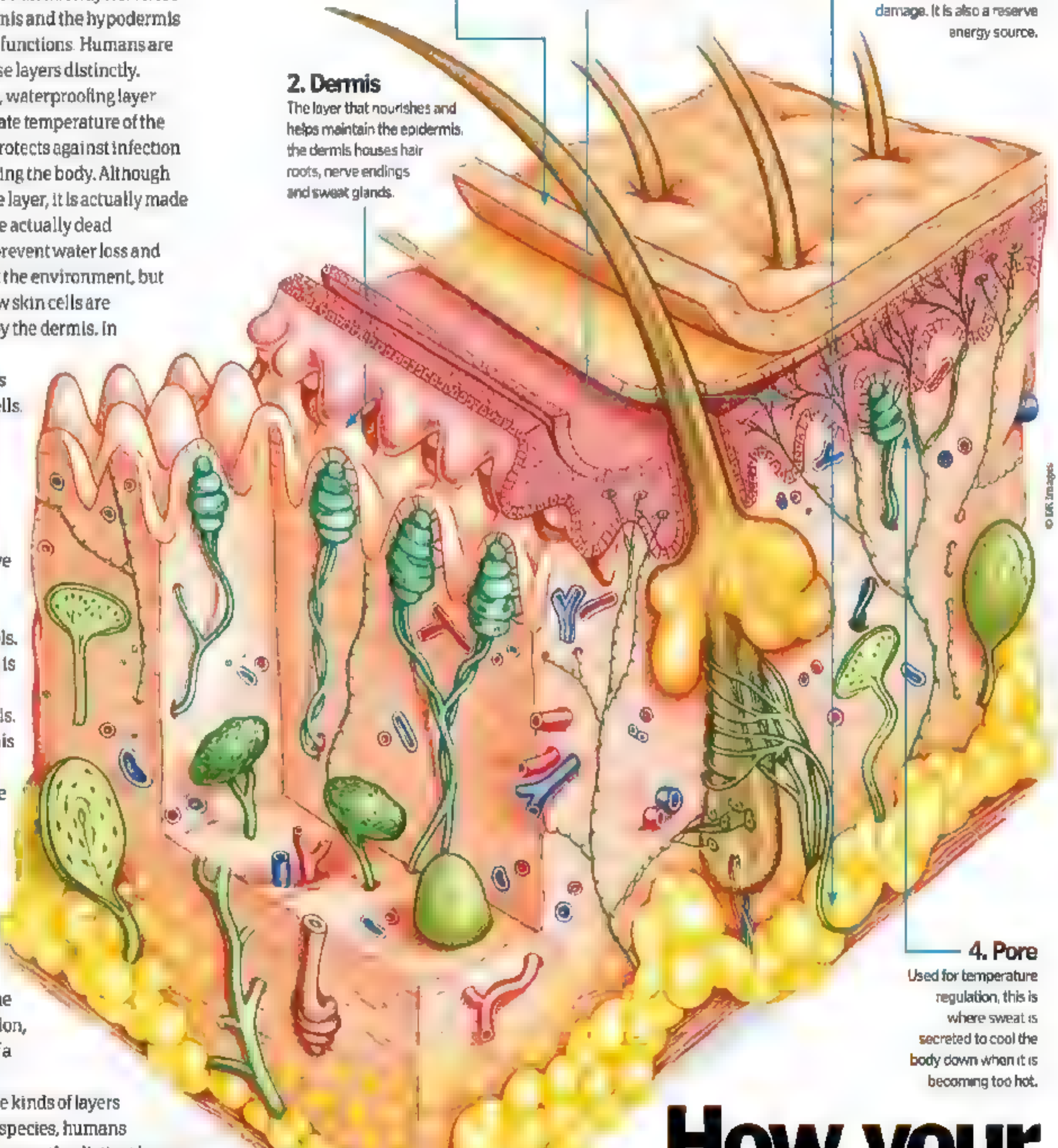
Find out more about the largest organ in your body…

Our skin is the largest organ in our bodies with an average individual skin's surface area measuring around two square metres and accounting for up to 16 per cent of total body weight. It is made up of three distinct layers. These are the epidermis, the dermis and the hypodermis and they all have differing functions. Humans are rare in that we can see these layers distinctly.

The epidermis is the top, waterproofing layer. Alongside helping to regulate temperature of the body, the epidermis also protects against infection as it stops pathogens entering the body. Although generally referred to as one layer, it is actually made up of five. The top layers are actually dead keratin-filled cells which prevent water loss and provide protection against the environment, but the lower levels, where new skin cells are produced, are nourished by the dermis. In other species, such as amphibians, the epidermis consists of only live skin cells. In these cases, the skin is generally permeable and actually may be a major respiratory organ.

The dermis has the connective tissue and nerve endings, contains hair follicles, sweat glands, lymphatic and blood vessels. The top layer of the dermis is ridged and interconnects securely with the epidermis.

Although the hypodermis is not actually considered part of the skin, its purpose is to connect the upper layers of skin to the body's underlying bone and muscle. Blood vessels and nerves pass through this layer to the dermis. This layer is actually crucial for all of the skins temperature regulation, as it contains 50 per cent of a healthy adult's body fat in subcutaneous tissue. These kinds of layers are not often seen in other species, humans being one of few that you can see the distinct layers within the skin. Not only does the skin offer protection for muscle, bone and internal organs, but it is our protective barrier against the environment. Temperature regulation, insulation, excretion of sweat and sensation are just a few more functions of skin.



How your skin works

The skin is made of many more elements than most people imagine

How the spleen works

Perhaps not as well-known as famous organs like the heart, the spleen serves vital functions that help keep us healthy

The spleen's main functions are to remove old blood cells and fight off infection. Red blood cells have an average life span of 120 days. Most are created from the marrow of long bones, such as the femur. When they're old, it's the spleen's job to identify them, filter them out and then break them down. The smaller particles are then sent back into the bloodstream, and either recycled or excreted from other parts of the body. This takes place in the 'red pulp', which are blood vessel-rich areas of the spleen that make up about three-quarters of its structure.

The remainder is called 'white pulp', which are areas filled with different types of immune cell (such as lymphocytes). They filter out and destroy foreign pathogens, which have invaded the body and are circulating in the blood. The white pulp breaks them down into smaller, harmless particles.

It is surrounded by a thin, fragile capsule and so is prone to injury. It sits beneath the lower ribs on the left-hand side of your body, which affords it some protection, but car crashes, major sports impacts and knife wounds can all rupture the organ. In the most serious cases, blood loss can endanger the person's life, and in these situations it needs to be removed by a surgeon. Since this reduces the body's ability to fight infections, some people will need to take antibiotics to boost their immunity for the rest of their lives.

The immune system

Although the red blood that flows through our bodies gets all the [illegible] the transparent lymphatic fluid is equally important. It has [illegible] body-wide network which follows blood vessel flow closely and [illegible] for the transport of digested fats, immune cells and more.

Spleen

[illegible] co-ordinators that actually [illegible] staves off infections and filters [illegible] old red blood cells. It contains a [illegible] of lymphocytes that [illegible]

[illegible] adults don't need on [illegible]

[illegible] are masses of lymphoid [illegible] of the throat [illegible] when the mouth [illegible] they form the first [illegible] line of defence [illegible]

Adenoids

[illegible] system that are only [illegible] children up until the age of two [illegible] in adults they have [illegible] They add an ex[illegible]

Bone marrow

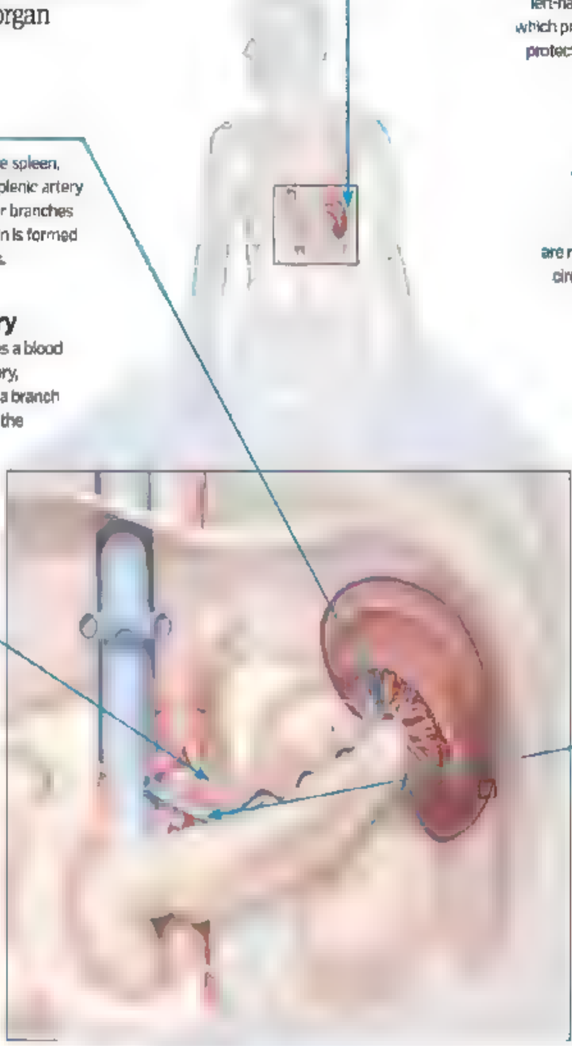
This forms the central [illegible]

Lymph nodes

These are small (about [illegible] 0.4in) spherical nodes that [illegible] packed with macrophages [illegible] lymphocytes to defend aga[illegible]

Inside the spleen

We take you on a tour of the major features in this often-overlooked organ

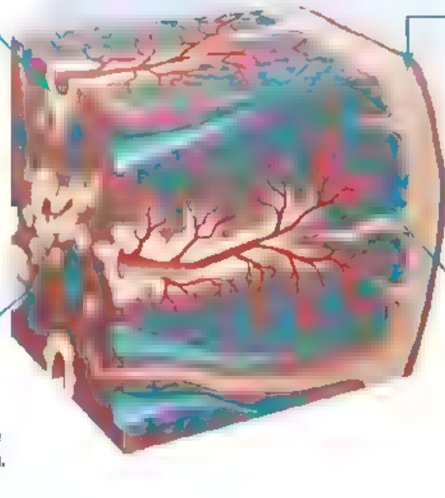


Location
The spleen sits underneath the 9th, 10th and 11th ribs (below the diaphragm) on the left-hand side of the body, which provides it with some protection against knocks.

Hilum
The entrance to the spleen, this is where the splenic artery divides into smaller branches and the splenic vein is formed from its tributaries.

Splenic vein
The waste products from filtration and pathogen digestion are returned to the main circulation via this vein for disposal.

Splenic artery
The spleen receives a blood supply via this artery, which arises from a branch of the aorta called the coeliac trunk.



White pulp
Making up roughly a quarter of the spleen, the white pulp is where white blood cells identify and destroy any type of invading pathogens.

Splenic capsule
The capsule provides some protection, but it's thin and relatively weak. Strong blows or knife wounds can easily rupture it and lead to life-threatening bleeding.

Red pulp
Forming approximately three-quarters of the spleen, the red pulp is where red blood cells are filtered and broken down.

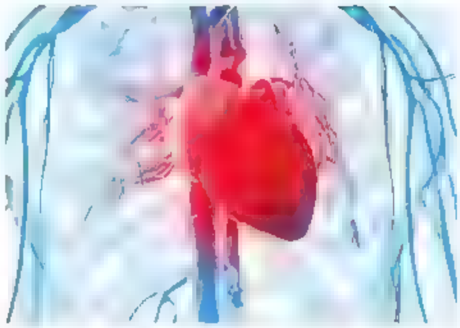
Sinusoid
Similar to those found in the liver, these capillaries allow for the easy passage of large cells into the splenic tissue for processing.

The human heartbeat

How one of your hardest-working muscles keeps your blood pumping

Your heart began to beat when you were a four-week-old foetus in the womb. Over the course of the average lifetime, it will beat over 2 billion times.

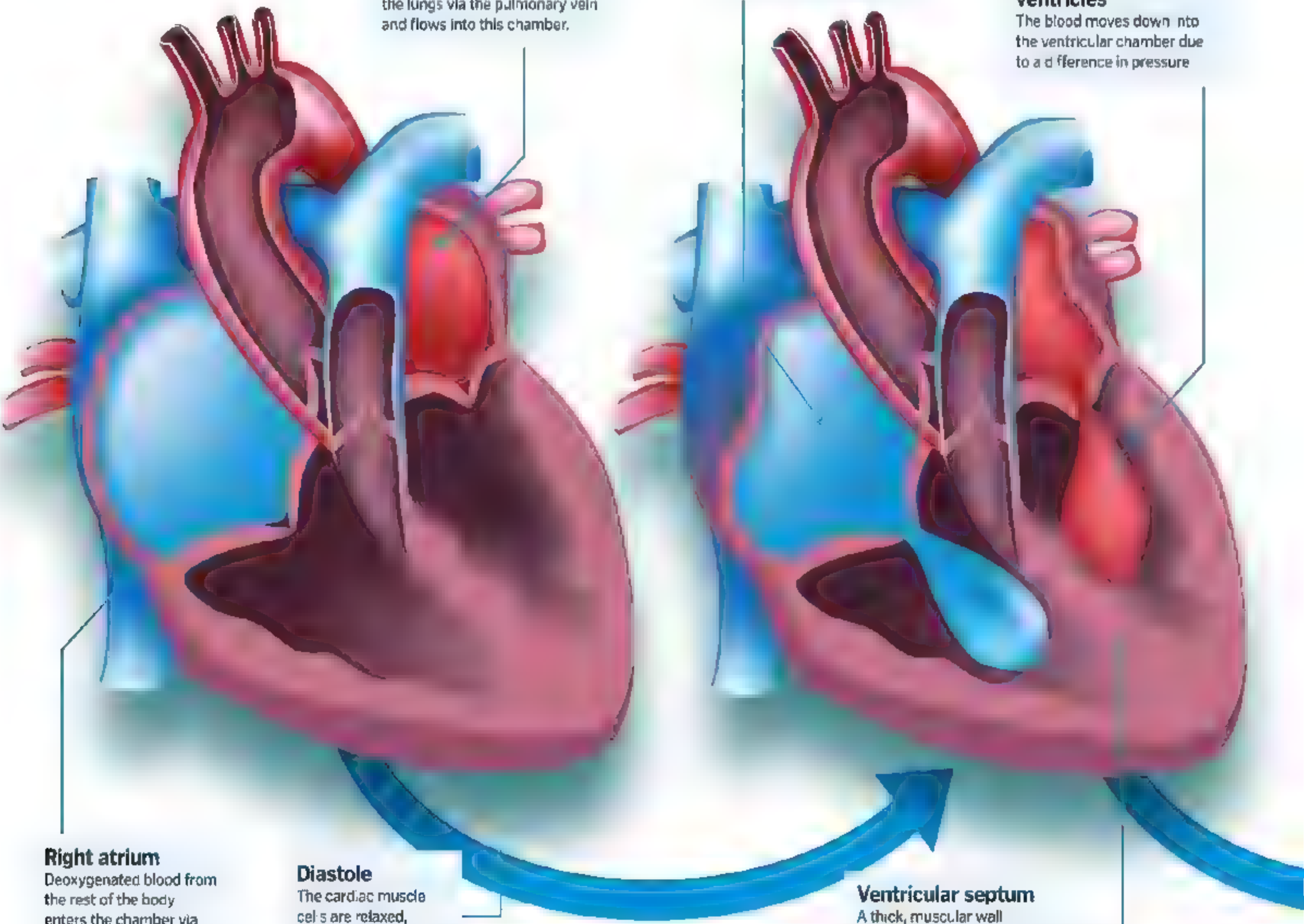
The heart is composed of four chambers separated into two sides. The right side receives deoxygenated blood from the body, and pumps it towards the lungs, where it picks up oxygen from the air you breathe. The oxygenated blood returns to the left side of the heart, where it is sent through the circulatory system, delivering oxygen and nutrients around the body. The pumping action of the heart is coordinated by muscular contractions that are generated by electrical currents. These currents regularly trigger cardiac contractions known as systole. The upper chambers, or atria, which receive blood arriving at the heart, contract first. This forces blood to the lower, more muscular chambers, known as ventricles, which then contract to push blood out to the body. Following a brief stage where the heart tissue relaxes, known as diastole, the cycle begins again.



The heart consists of four chambers, separated into two sides

The cardiac cycle

A single heartbeat is a series of organised steps that maximise blood-pumping efficiency

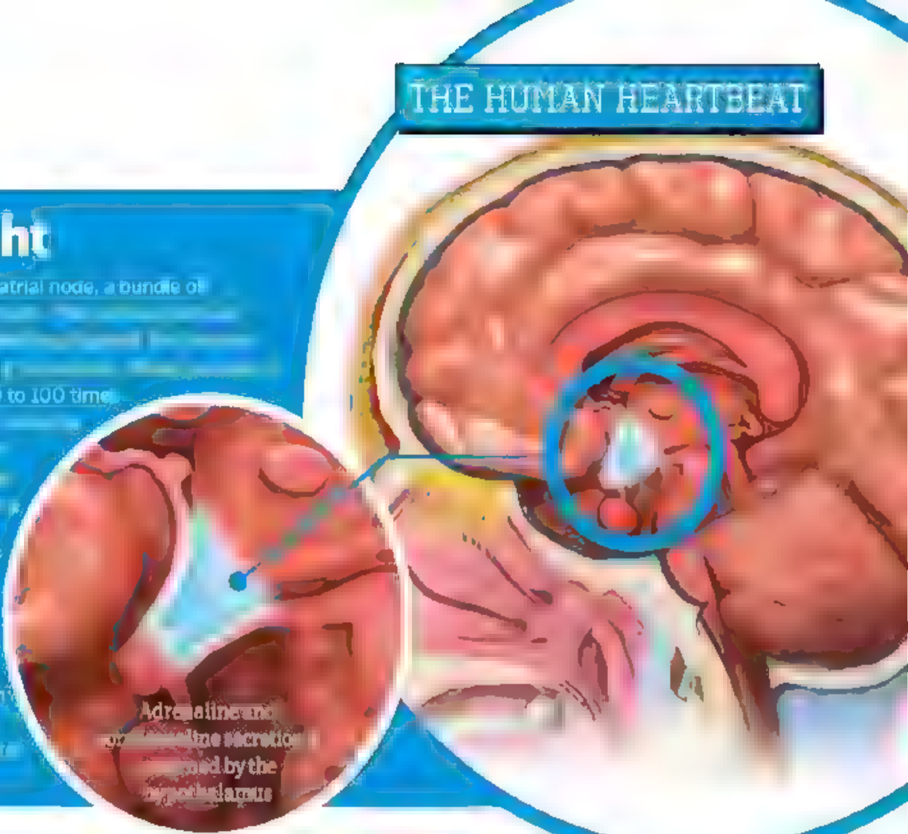


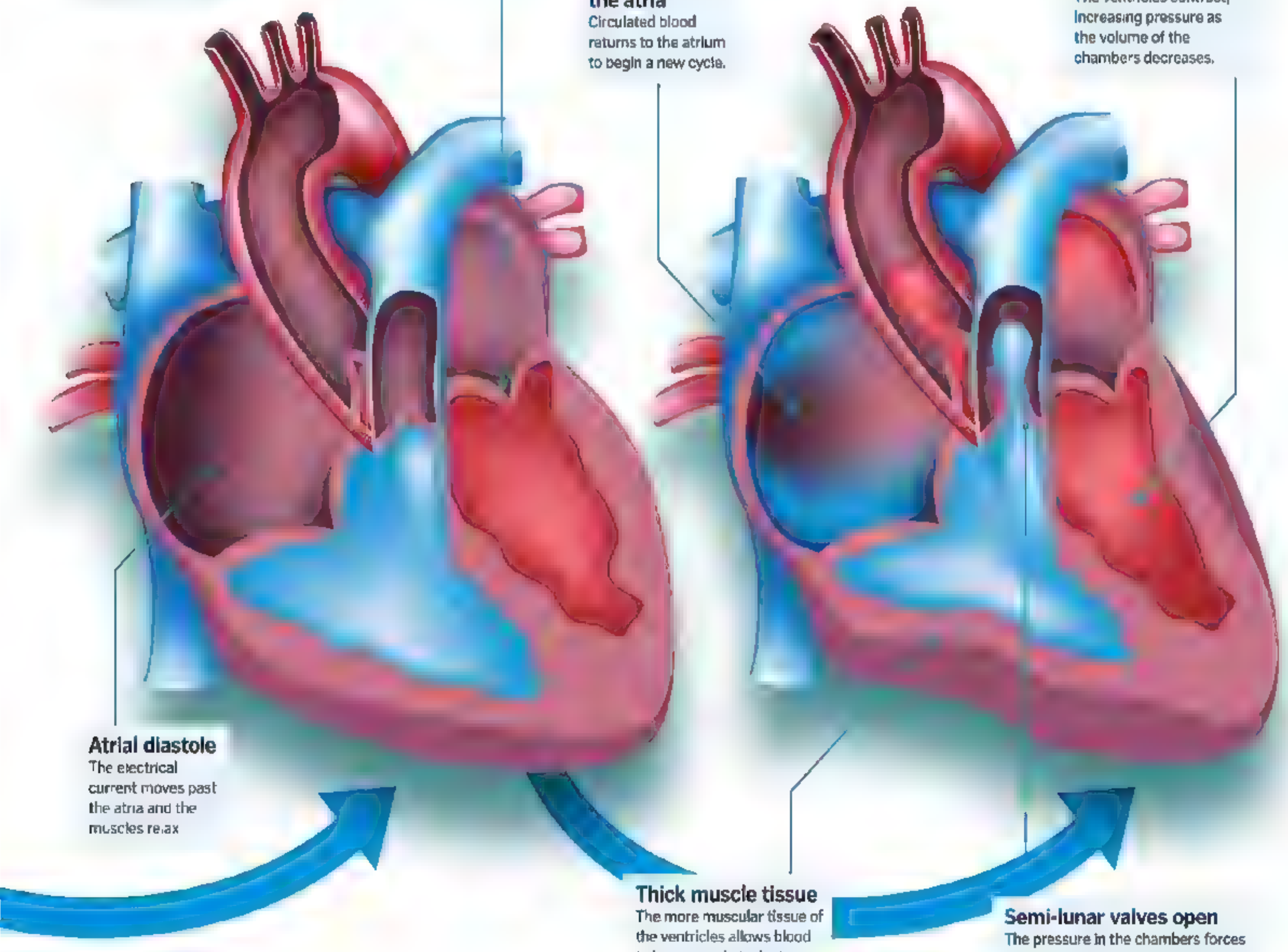
"Over the course of the average lifetime, the heart will beat over 2 billion times"

Fight or flight

A heartbeat begins at the sinoatrial node, a bundle of [illegible] rest, this happens between 60 to 100 time[illegible]

This results in [illegible] conductance of the sinoatrial node, increasing heart rate and so providing the body with more available nutrients t[illegible] either fight for survival or run f[illegible]





Inside the human stomach

Discover how this amazing digestive organ stretches, churns and holds corrosive acid to break down our food, all without getting damaged

The stomach's major role is as a reservoir for food; it allows large meals to be consumed in one sitting before being gradually emptied into the small intestine. A combination of acid, protein-digesting enzymes and vigorous churning action breaks the stomach contents down into an easier-to-process liquid form, preparing food for absorption in the bowels.

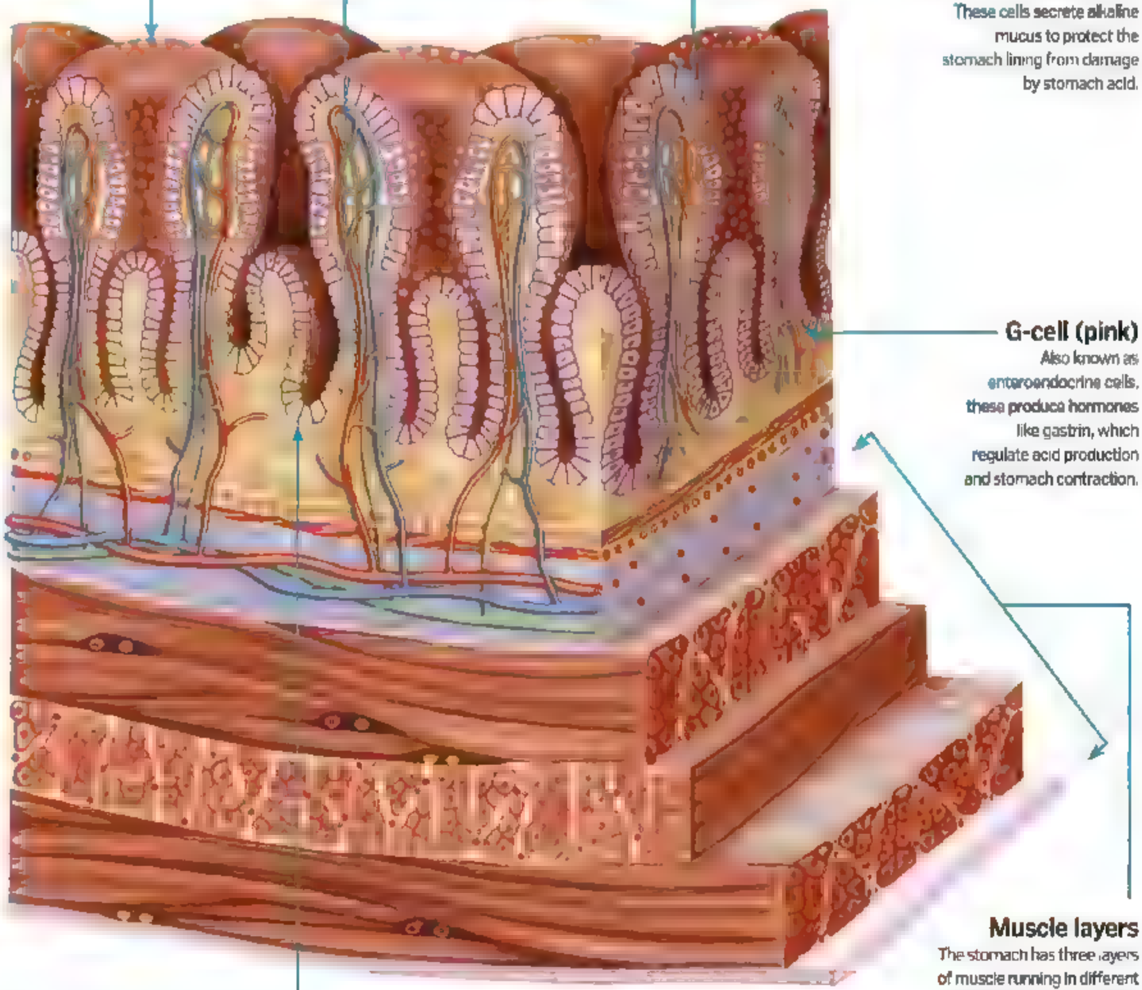
In its resting state, the stomach is contracted and the internal surface of the organ folds into characteristic ridges, or rugae. When we start eating, however, the stomach begins to distend, the rugae flatten, allowing the stomach to expand, and the outer muscles relax. The stomach can accommodate about a litre (1.8 pints) of food without any discomfort.

The expansion of the stomach activates stretch receptors, which trigger nerve signalling that results in increased acid production and powerful muscle contractions to mix and churn the contents. Gastric acid causes proteins in the food to unravel, allowing access by the enzyme pepsin, which breaks down protein. The presence of partially digested proteins stimulates enteroendocrine cells (G-cells) to make the hormone gastrin, which encourages even more acid production.

The stomach empties its contents into the small intestine through the pyloric sphincter. Liquids pass through the sphincter easily, but solids must be smaller than one to two millimetres (0.04-0.08 inches) in diameter before they will fit. Anything larger is 'refluxed' backwards into the main chamber for further churning and enzymatic breakdown. It takes about two hours for half a meal to pass into the small intestine and the process is generally complete within four to five hours.

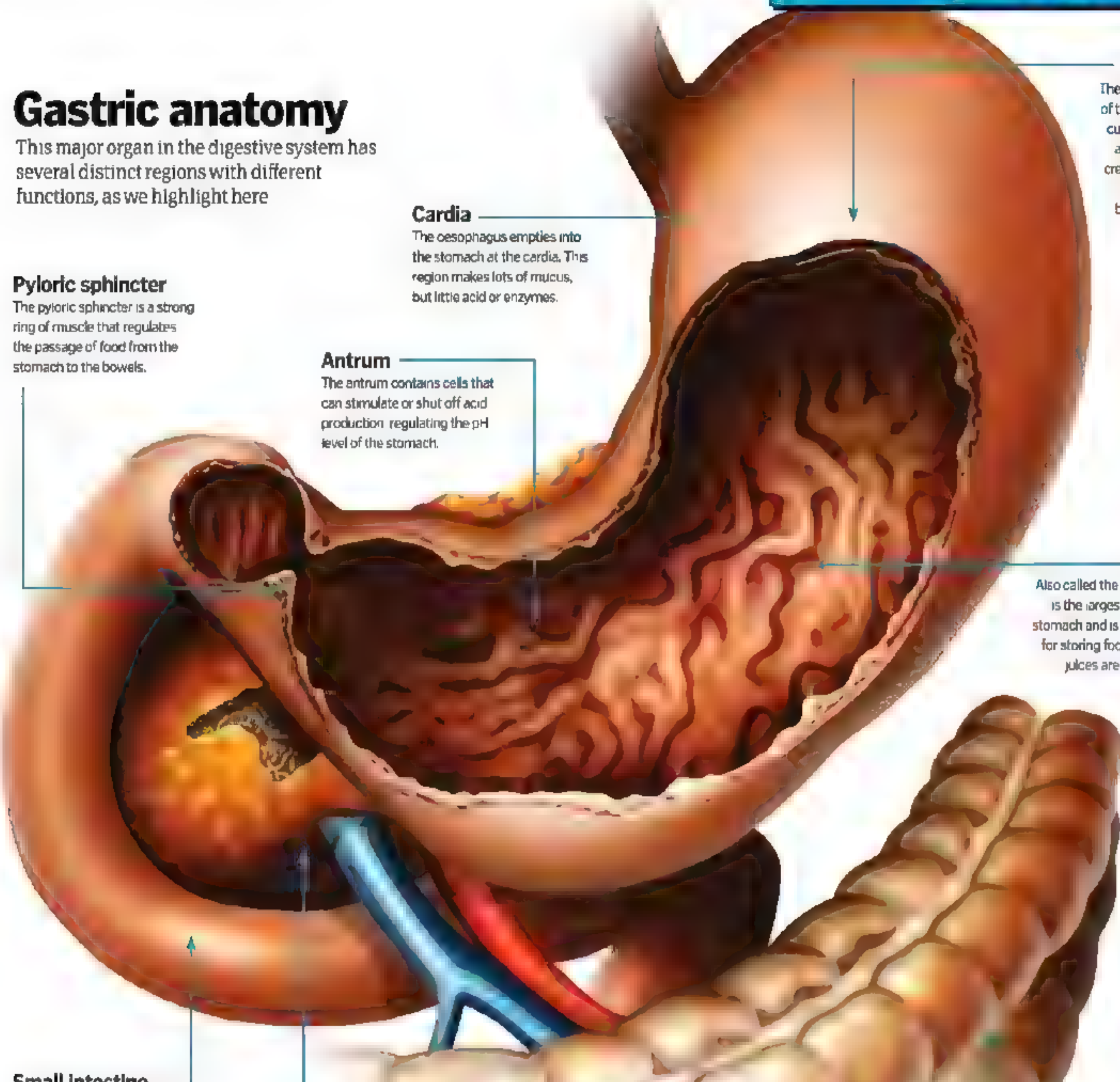
Lining under the microscope

The stomach is much more than just a storage bag. Take a look at its complex microanatomy now...



Gastric anatomy

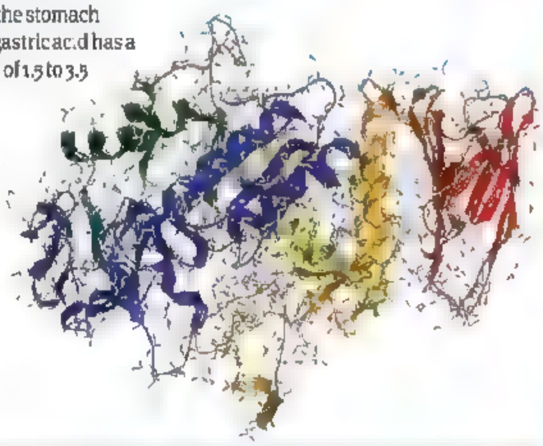
This major organ in the digestive system has several distinct regions with different functions, as we highlight here



Why doesn't it digest itself?

Your stomach is full of corrosive acid and enzymes capable of breaking down protein – if left unprotected the stomach lining would quickly be destroyed. To prevent this from occurring, the cells lining the stomach wall produce carbohydrate-rich mucus, which forms a slippery, gel-like barrier. The mucus contains bicarbonate, which is alkaline and buffers the pH at the surface of the stomach lining, preventing damage by acid. For added protection, the protein-digesting enzyme pepsin is created from a zymogen (the enzyme in its inactive form) – pepsinogen; it only becomes active when it comes into contact with acid, a safe distance away from the cells that manufacture it.

Produced by parietal cells in the stomach lining, gastric acid has a pH level of 1.5 to 3.5



Vomit reflex step-by-step

[illegible]

Kidney function

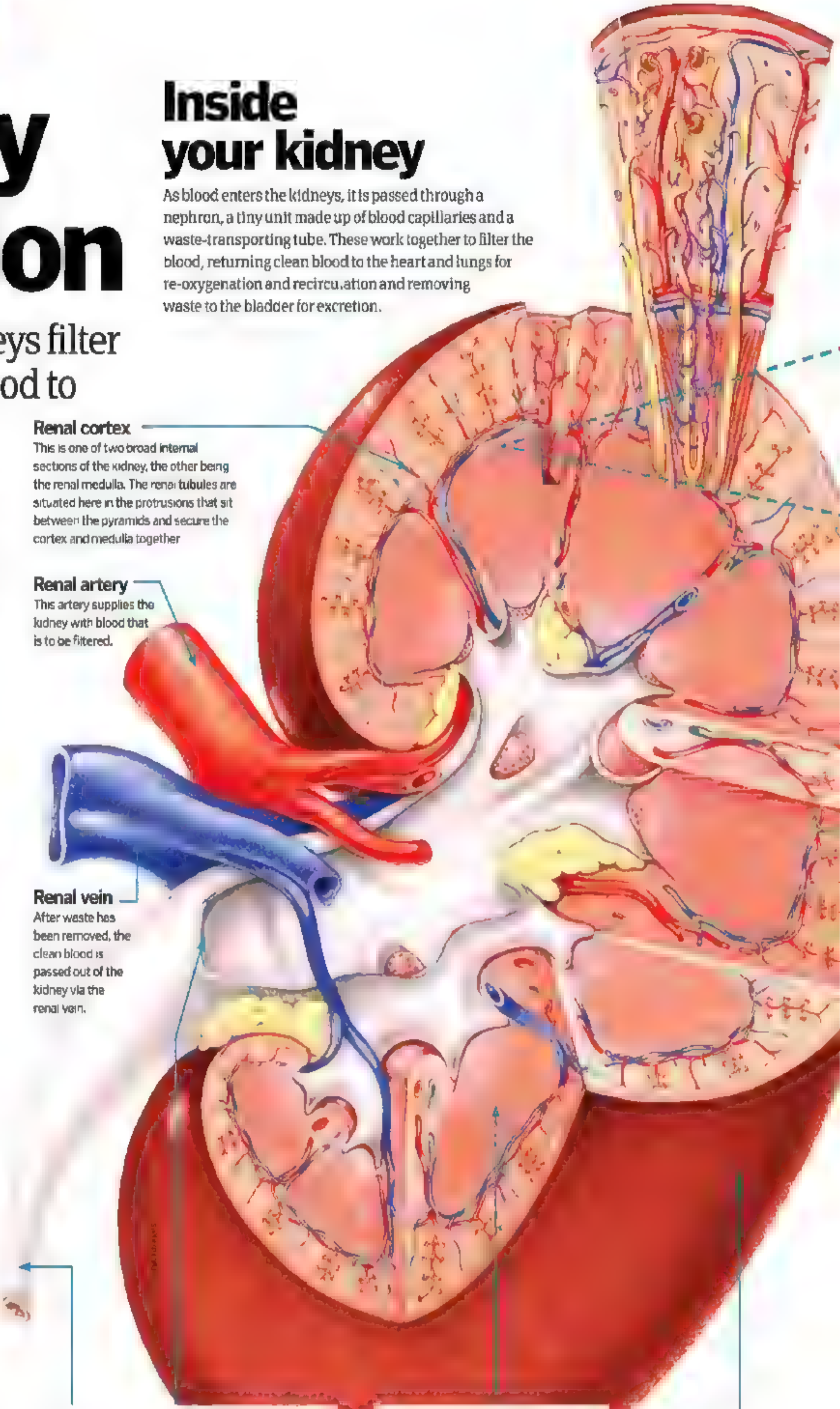
How do your kidneys filter waste from the blood to keep you alive?

Kidneys are two bean-shaped organs situated halfway down the back just under the ribcage, on each side of the body, and weigh between 115 and 170 grams each, dependent on the individual's sex and size. The left kidney is commonly a little larger than the right and due to the effectiveness of these organs, individuals born with only one kidney can survive with little or no adverse health problems. Indeed, the body can operate normally with a 30-40 per cent decline in kidney function. This decline in function would rarely even be noticeable and shows just how effective the kidneys are at filtering out waste products as well as maintaining mineral levels and blood pressure throughout the body. The kidneys manage to control all of this by working with other organs and glands across the body such as the hypothalamus, which helps the kidneys determine and control water levels in the body. Each day the kidneys will filter between a staggering 150 and 180 litres of blood, but only pass around two litres of waste down the ureters to the bladder for excretion. This waste product is primarily urea – a by-product of protein being broken down for energy – and water, and it's more commonly known as 'urine'. The kidneys filter the blood by passing it through a small filtering unit called a nephron. Each kidney has around a million of these, which are made up of a number of small blood capillaries, called glomerulus, and a urine-collecting tube called the renal tubule. The glomerulus sift the normal cells and proteins from the blood and then move the waste products into the renal tubule, which transports urine down into the bladder through the ureters.

Alongside this, the kidneys also release three hormones (known as erythropoietin, renin and calcitriol) which encourage red blood cell production, aid regulation of blood pressure and aid bone development and mineral balance respectively.

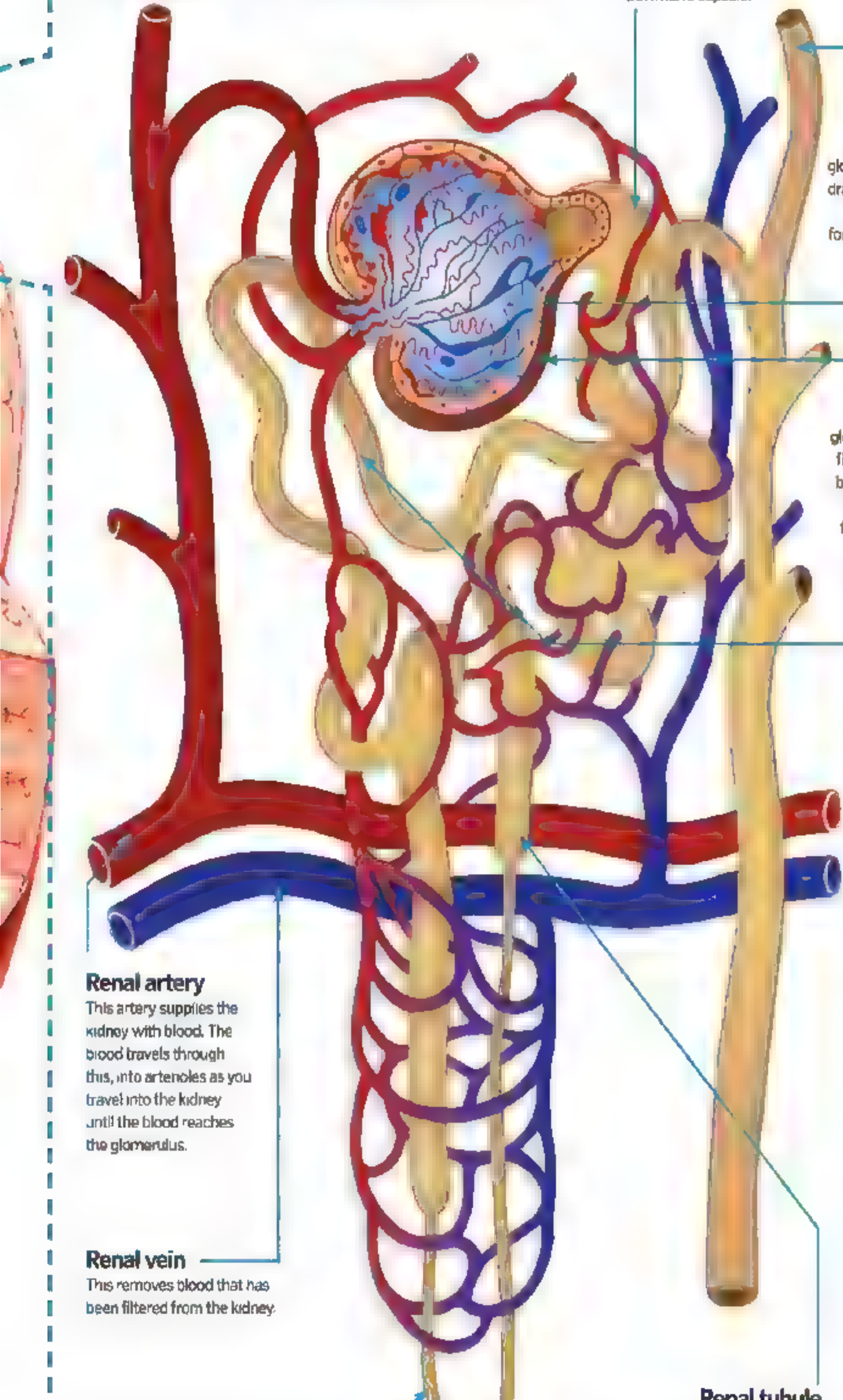
Inside your kidney

As blood enters the kidneys, it is passed through a nephron, a tiny unit made up of blood capillaries and a waste-transporting tube. These work together to filter the blood, returning clean blood to the heart and lungs for re-oxygenation and recirculation and removing waste to the bladder for excretion.



Nephrons – the filtration units of the kidney

Nephrons are the units which filter all blood that passes through the kidneys. There are around a million in each kidney, situated in the renal medulla's pyramid structures. As well as filtering waste, nephrons regulate water and mineral salt by recirculating what is needed and excreting the rest.



Proximal tubule
Links Bowman's capsule and the loop of Henle, and will selectively reabsorb minerals from the filtrate produced by Bowman's capsule.

Collecting duct system
Although not technically part of the nephron, this collects all waste product filtered by the nephrons and facilitates its removal from the kidneys.

Glomerulus
High pressure in the glomerulus, caused by it draining into an arteriole instead of a venule, forces fluids and soluble materials out of the capillary and into Bowman's capsule.

Bowman's capsule
Also known as the glomerular capsule, this filters the fluid that has been expelled from the glomerulus. Resulting filtrate is passed along the nephron and will eventually make up urine.

Distal convoluted tubule
Partly responsible for the regulation of minerals in the blood, linking to the collecting duct system. Unwanted minerals are excreted from the nephron.

Renal artery
This artery supplies the kidney with blood. The blood travels through this, into arterioles as you travel into the kidney until the blood reaches the glomerulus.

Renal vein
This removes blood that has been filtered from the kidney.

Loop of Henle
The loop of Henle controls the mineral and water concentration levels within the kidney to aid filtration of fluids as necessary. It also controls urine concentration.

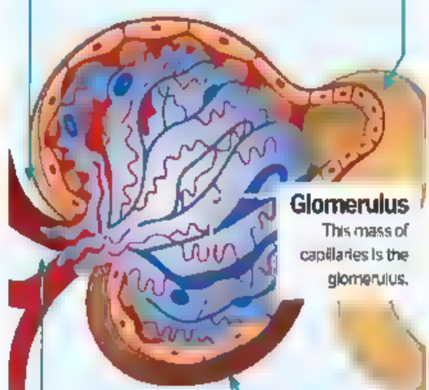
Renal tubule
Made up of three parts, the proximal tubule, the loop of Henle and the distal convoluted tubule. They remove waste and reabsorb minerals from the filtrate passed on from Bowman's capsule.

The glomerulus

This group of capillaries is the first step of filtration and a crucial aspect of a nephron. As blood enters the kidneys via the renal artery, it is passed down through a series of arterioles which eventually lead to the glomerulus. This is unusual, as instead of draining into a venule (which would lead back to a vein) it drains back into an arteriole, which creates much higher pressure than normally seen in capillaries, which in turn forces soluble materials and fluids out of the capillaries. This process is known as ultrafiltration and is the first step in filtration of the blood. These then pass through the Bowman's capsule (also know as the glomerular capsule) for further filtration.

Afferent arteriole
This arteriole supplies the blood to the glomerulus for filtration.

Proximal tubule
Where reabsorption of minerals from the filtrate from Bowman's capsule will occur.



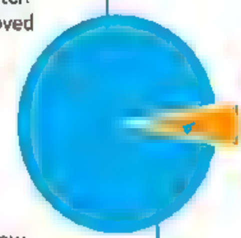
Glomerulus
This mass of capillaries is the glomerulus.

Efferent arteriole
This arteriole is how blood leaves the glomerulus following ultrafiltration.

Bowman's capsule
This is the surrounding capsule that will filter the filtrate produced by the glomerulus.

What is urine and what is it made of?

Urine is made up of a range of organic compounds such as various proteins and hormones, inorganic salts and numerous metabolites. These are often rich in nitrogen and need to be removed from the blood stream through urination. The pH-level of urine is typically around neutral (pH7) but varies depending on diet, hydration levels and physical fitness. The colour of urine is also determined by all of these different factors playing a part, with dark yellow urine indicating dehydration and greenish urine being indicative of excessive asparagus consumption.



How the liver works

The human liver is the ultimate multitasker. It performs many different functions all at the same time without you asking

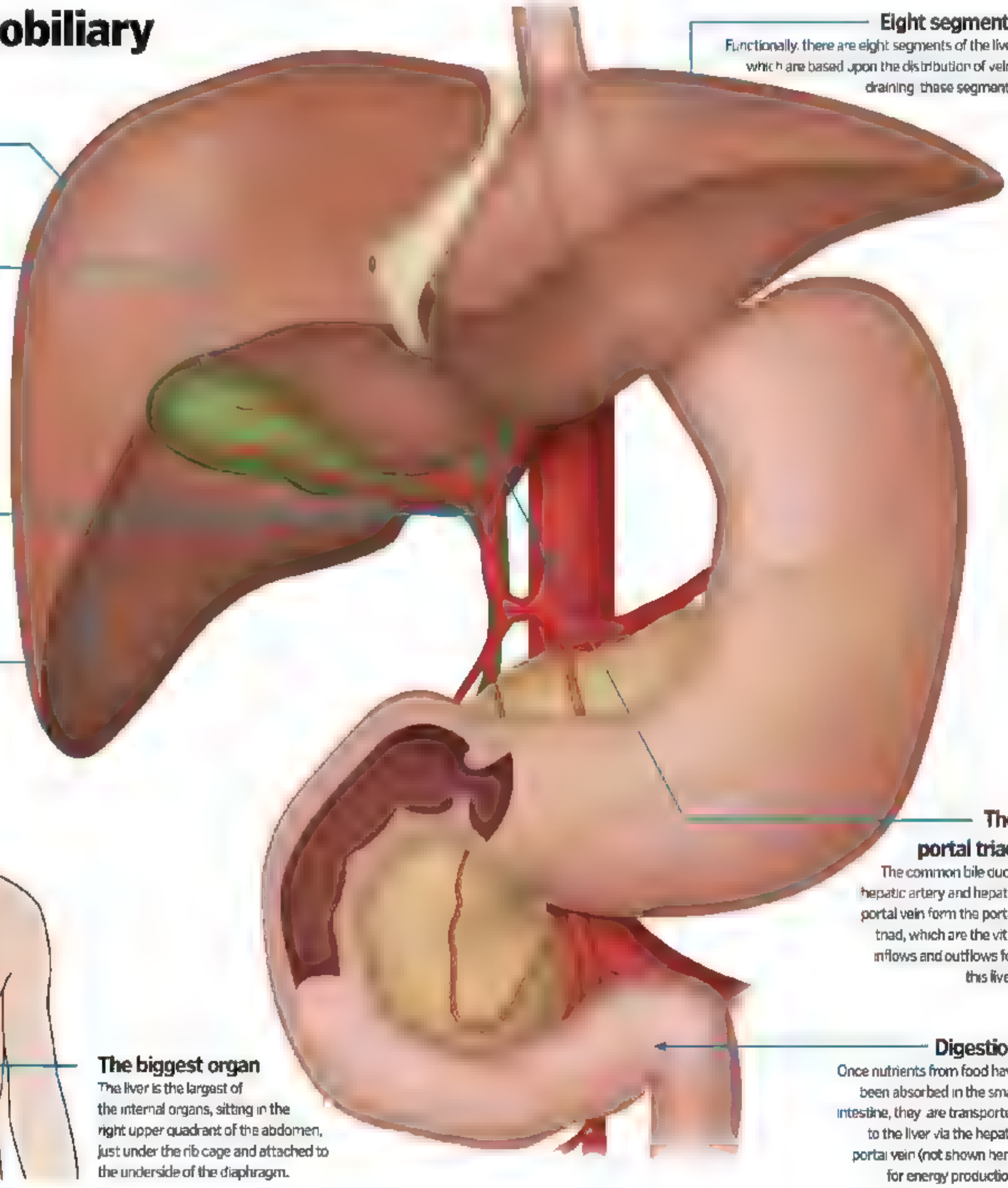
The liver is actually the largest internal organ in the human body and, has over 500 different functions. In fact, it is actually the second most complex organ after the brain and is intrinsically involved in almost every aspect of the body's metabolic processes.

The liver's main functions in the body are energy production, removal of harmful substances and the production of crucial proteins. These tasks are carried out within liver cells, called hepatocytes, which sit in complex arrangements to maximise their overall efficiency.

The liver is the body's main powerhouse, producing and storing glucose as a key energy source. It is also responsible for breaking down complex fat molecules and building them up into cholesterol and triglycerides, which the body needs but in excess are bad. The liver makes many complex proteins, including clotting factors which are vital in arresting bleeding. Bile, which helps digest fat in the intestines, is produced in the liver and stored in the adjacent gallbladder.

The liver also plays a key role in detoxifying the blood. Waste products, toxins and drugs are

The hepatobiliary region



Two halves
The liver is anatomically split into two halves: left and right. There are four lobes, and the right lobe is the largest.

The gallbladder
The gallbladder and liver are intimately related. Bile, which helps digest fat, is produced in the liver and stored in the gallbladder

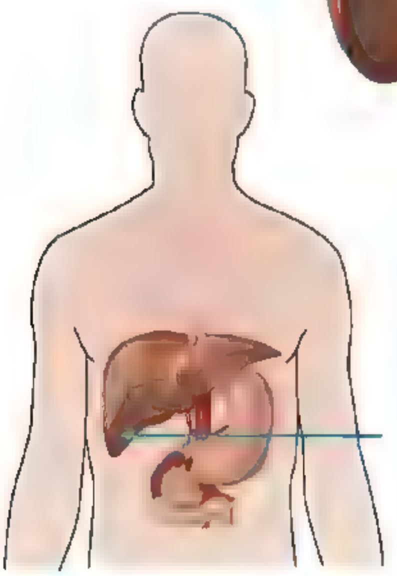
The common bile duct
This duct is small, but vital in the human body. It carries bile from the liver and gallbladder into the duodenum where it helps digest fat.

Feel your liver
Take a deep breath in and feel just under the right lower edge of your ribs – in some people the lower edge of the liver can be felt.

Eight segments
Functionally, there are eight segments of the liver, which are based upon the distribution of veins draining these segments.

The portal triad
The common bile duct, hepatic artery and hepatic portal vein form the portal triad, which are the vital inflows and outflows for this liver.

Digestion
Once nutrients from food have been absorbed in the small intestine, they are transported to the liver via the hepatic portal vein (not shown here) for energy production.



The biggest organ
The liver is the largest of the internal organs, sitting in the right upper quadrant of the abdomen, just under the rib cage and attached to the underside of the diaphragm.

"The liver also breaks down old blood cells and recycles hormones such as adrenaline"

processed here into forms which are easier for the rest of the body to use or excrete. The liver also breaks down old blood cells, produces antibodies to fight infection and recycles hormones such as adrenaline. Numerous essential vitamins and minerals are stored in the liver: vitamins A, D, E and K, iron and copper.

Such a complex organ is also unfortunately prone to diseases. Cancers, infections (hepatitis) and cirrhosis (a form of fibrosis which is often caused by excess alcohol consumption) are just some of those which can affect the liver

gallstones are common but usually don't cause problems

The gallbladder

Bile, a dark green slimy liquid, is produced in the hepatocytes and helps to digest fat. It is stored in a reservoir which sits on the under-surface of the liver, to be used when needed. This reservoir is called the gallbladder. Stones can form in the gallbladder (gallstones) and are very common, although most don't cause problems. In 2009, just under 60,000 gallbladders were removed from patients within the NHS making it one of the most common operations performed; over 90 per cent of these are removed via keyhole surgery. Most patients do very well without their gallbladder and don't notice any changes at all

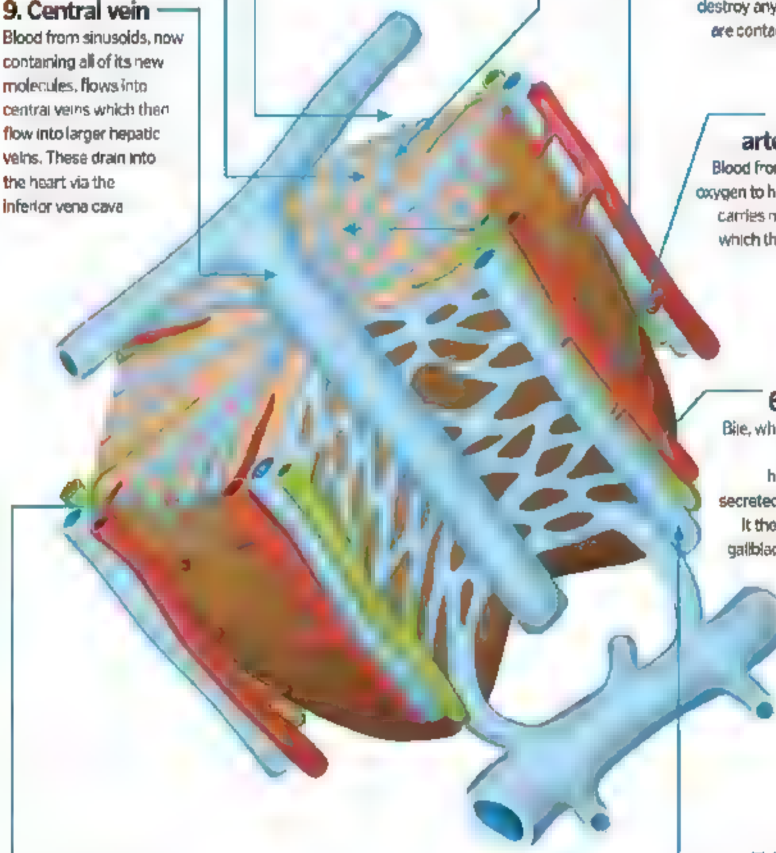
A high-demand organ

The liver deals with a massive am... blood. It is unique because it has ... supplies. 75 per cent of th... from the intestines (via the hepatic por... in) which carries nutrients from d... the liver processes and turns in... comes from the ... which branches ... aorta), carrying oxygen which the liver need... to produce th... ween the liver cells where the many ... olic functions occur. The blood ... he liver via the hepatic veins to flow into the biggest vein in the body – the inferior ...

Liver lobules

The functional unit which performs the liver's tasks

The liver is considered a 'chemical factory,' as it forms large complex molecules from smaller ones brought to it from the gut via the blood stream. The functional unit of the liver is the lobule – these are hexagonal-shaped structures comprising of blood vessels and sinusoids. Sinusoids are the specialised areas where blood comes into contact with the hepatocytes, where the liver's biological processes take place.



1. The lobule
This arrangement of blood vessels, bile ducts and hepatocytes form the functional unit of the liver

2. The hepatocyte
These highly active cells perform all of the liver's key metabolic tasks.

3. Sinusoids
These blood-filled channels are lined by hepatocytes and provide the site of transfer of molecules between blood and liver cells.

4. Kupffer cells
These specialised cells sit within the sinusoids and destroy any bacteria which are contaminating blood.

5. Hepatic artery branch
Blood from here supplies oxygen to hepatocytes and carries metabolic waste which the liver extracts.

6. Bile duct
Bile, which helps digest fat, is made in hepatocytes and secreted into bile ducts. It then flows into the gallbladder for storage before being secreted into the duodenum.

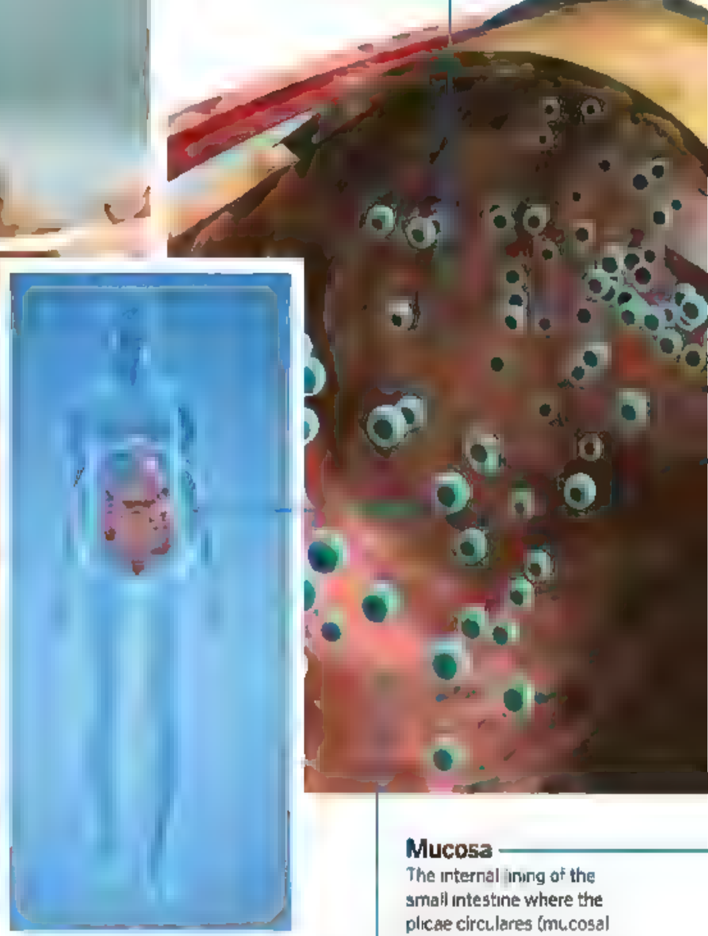
7. Portal vein
This vein carries nutrient-rich blood directly from the intestines, which flows into sinusoids for conversion into energy within hepatocytes.

8. The portal triad
The hepatic artery, portal vein and bile duct are known as the portal triad. These sit at the edges of the liver lobule and are the main entry and exit routes for the liver.

9. Central vein
Blood from sinusoids, now containing all of its new molecules, flows into central veins which then flow into larger hepatic veins. These drain into the heart via the inferior vena cava

Structure of the small intestine

Examine the anatomy of this vital organ in the human digestive tract



Lumen
This is the space inside the small intestine in which the food travels to be digested and absorbed

Mucosa
The internal lining of the small intestine where the plicae circulares (mucosal folds) and villi are situated.

Mucosal folds
These line the small intestine to increase surface area and help push the food on its way by creating a valve-like structure, stopping food travelling backwards.

Submucosa This supports the mucosa and connects it to the layers of muscle (muscularis) that make up the exterior of the small intestine.

Exploring the small intestine

Crucial for getting the nutrients we need from the food we eat, how does this digestive organ work?

The small intestine is actually one of the most important elements of our digestive system, which enables us to process food and absorb nutrients. On average, it sits at a little over six metres, that is 19.7 feet, long with a diameter of 2.5-3 centimetres, 1-1.2 inches. The small intestine is made up of three different distinctive parts: the duodenum, jejunum and the ileum.

The duodenum actually connects the small intestine to the stomach and is the key place for further enzyme breakdown, following already passing through the stomach, turning food into an amino acid state. While the duodenum is very important in breaking food down, using bile and enzymes from the gallbladder, liver and pancreas, it is actually the shortest element of the small bowel, only averaging about 30 centimetres, which is just 11.8 inches. The jejunum follows the duodenum and its primary function is to encourage absorption of carbohydrates and proteins by passing the broken-down food molecules through an area with a large surface area so they can enter the bloodstream. Villi – small finger-like structures – and mucosal folds line the passage and increase the surface area dramatically to aid this process.

The ileum is the final section of the small bowel and its main purpose is to catch nutrients that may have been missed, as well as absorbing vitamin B12 and bile salts.

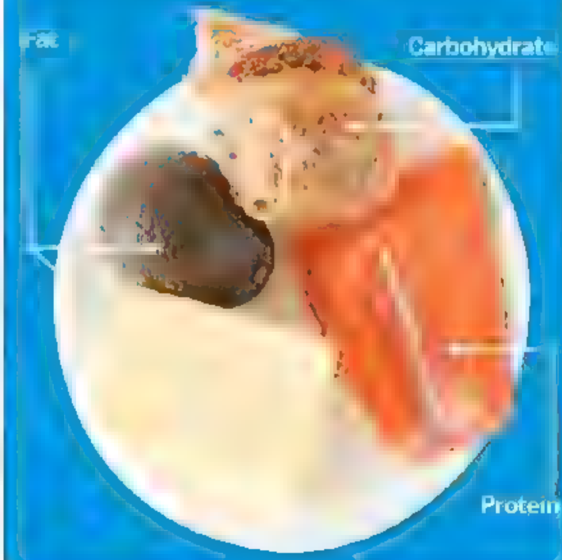
Peristalsis is the movement used by the small intestine to push the food through to the large bowel, where waste matter is stored for a short period then disposed of via the colon. This process is automatically generated by a series of different muscles which make up the organ's outer wall.

Serosa
This protective outer layer stops the small intestine from be ng damaged by other organs.

Nutrients
Nutrients move through the tube-like organ to be d ffused into the body, mainly via the bloodstream

What exactly are nutrients?

There are three main typ[illegible] carbohydrates and proteins. These three [illegible] s are brok[illegible] mpler molecule elements, which we can [illegible] hrough th[illegible] small intestine walls and that then travel [illegible] the bloodstrea[illegible] r muscles and other areas of the body tha[illegible] nd absorb[illegible] and minerals that we can't synthesise within the body, eg vita[illegible]in B12 (prevalent in meat and fis[illegible]



Blood vessels
These sit close to the small intestine to allow easy diffusion of nutrients into the bloodstream.

Circular muscle layer
This works in partnership with the longitudinal muscle layer to push the food down via a process called peristalsis.

Longitudinal muscle layer
This contracts and extends to help transport food with the circular muscle layer.

Villi
Villi are tiny finger-like structures that sit all over the mucosa They help ncrease the surface area massively, alongside the mucosal folds.

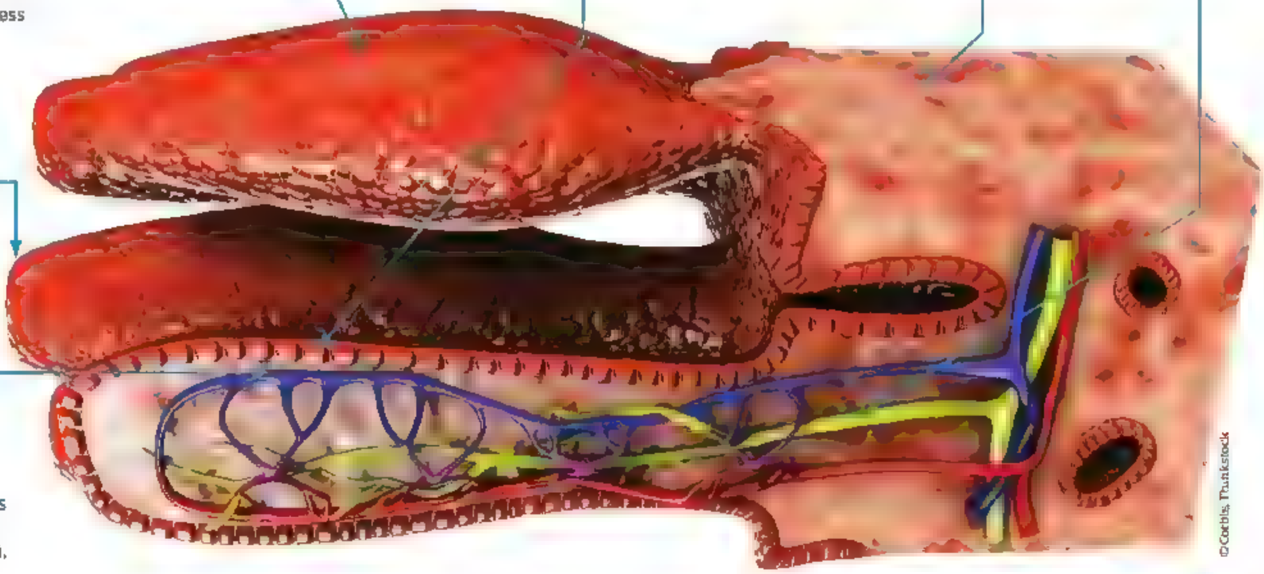
A closer look at villi

What role do these little finger-like protrusions play in the bowel?

Epithelium (epithelial cells)
These ndividual cells that sit n the mucosa layer are where ind vidual microvilli extend from.

Mucosa
The lining of the small intestine on which villi are located.

Lacteal
The lacteal is a lymphatic cap llary that absorbs nutrients that can't pass direct y into the bloodstream.



Microvilli
These are a mini version of villi and s t on vi li's individua epithelial cells.

Capillary bed
These absorb simple sugars and amino acids as they pass through the epithelial tissue of the villi.

How the pancreas works

Learn how the workhorse of the digestive system helps to break down food and control our blood sugar levels

The pancreas is a pivotal organ within the digestive system. It sits inside the abdomen, behind the stomach and the large bowel, adjacent to the spleen. In humans, it has a head, neck, body and tail. It is connected to the first section of the small intestine, the duodenum, by the pancreatic duct, and to the bloodstream via a rich network of vessels. When it comes to the function of the pancreas, it is best to think about the two types of cell it contains: endocrine and exocrine.

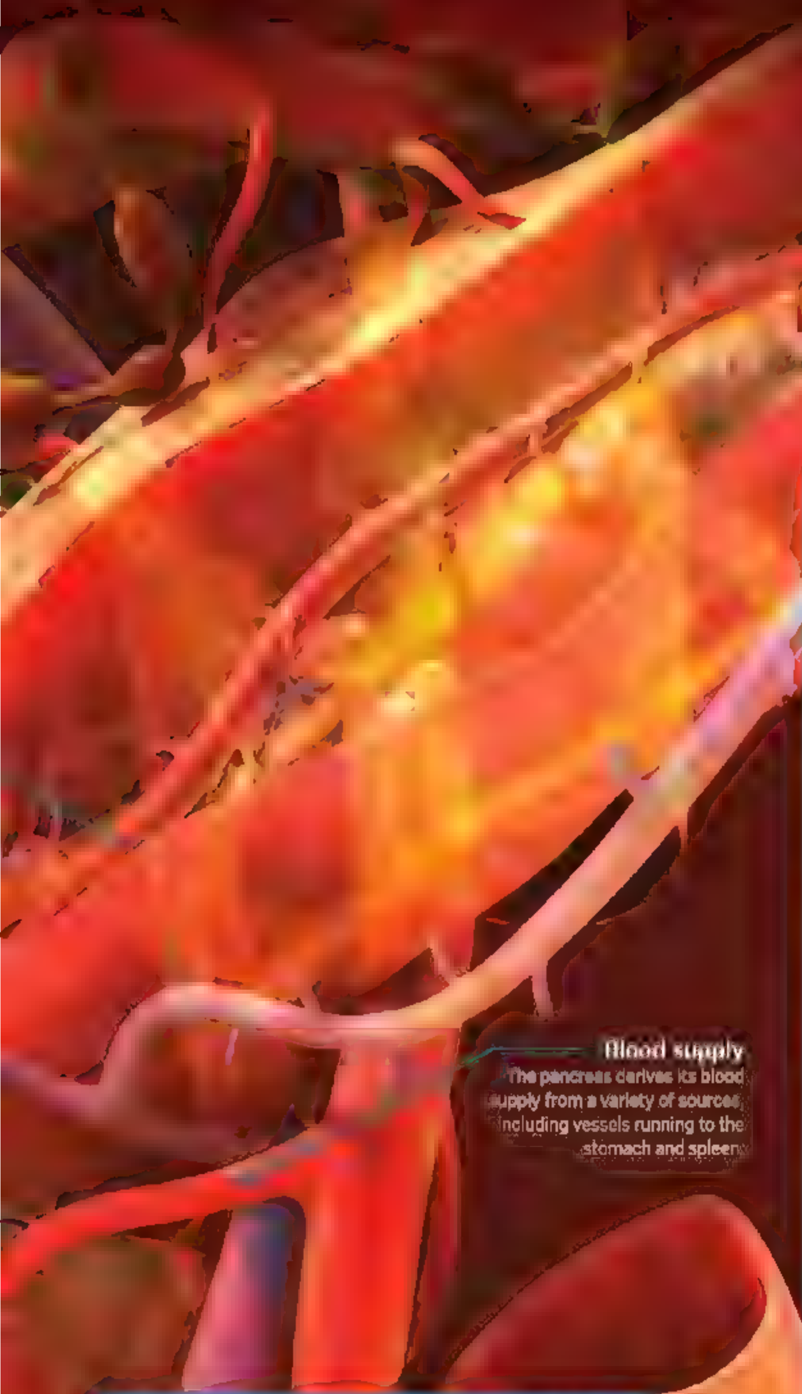
The endocrine pancreas is made up of clusters of cells called islets of Langerhans, which in total contain approximately 1 million cells and are responsible for producing hormones. These cells include alpha cells, which secrete glucagon, and beta cells which generate insulin. These two hormones have opposite effects on blood sugar levels throughout the body: glucagon increases glucose levels, while insulin decreases them.

The cells here are all in contact with capillaries, so hormones which are produced can be fed directly into the bloodstream. Insulin secretion is under the control of a negative-feedback loop; high blood sugar will lead to insulin secretion, which then lowers blood sugar with subsequent suppression of insulin. Disorders of these cells (and thus alterations of the hormone levels) can lead to many serious conditions, including diabetes. The islets of Langerhans are also responsible for producing other hormones, like somatostatin, which governs nutrient absorption among many other things.

The exocrine pancreas, meanwhile, is responsible for secreting digestive enzymes. Cells are arranged in clusters called acini, which flow into the central pancreatic duct. This leads into the duodenum – part of the small bowel – to come into contact with and aid in the digestion of food. The enzymes secreted include proteases (to digest protein), lipases (for fat) and amylase (for sugar/starch). Secretion of these enzymes is controlled by a series of hormones, which are released from the stomach and duodenum in response to the stretch from the presence of food.

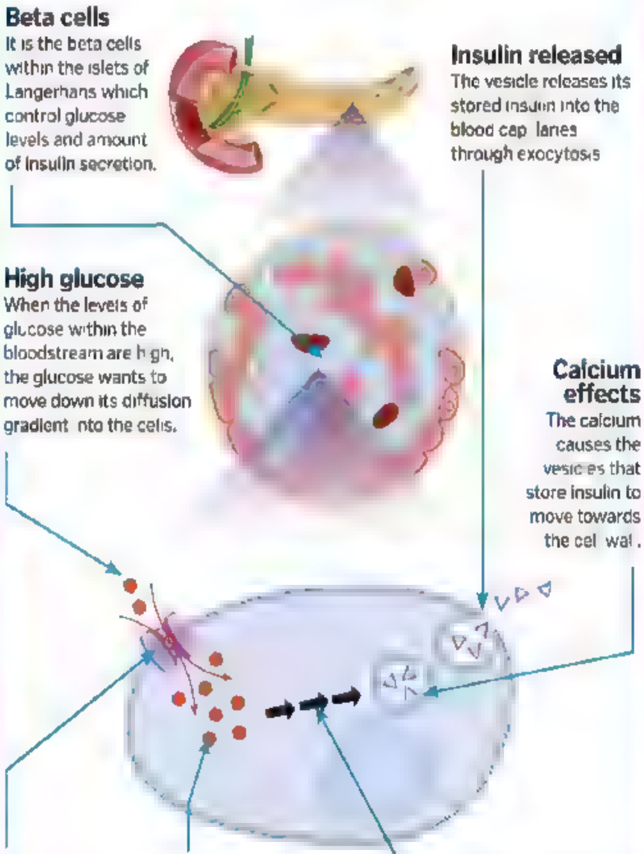
Anatomy of the pancreas

It might not be the biggest organ but the pancreas is a key facilitator of how we absorb nutrients and stay energised



What brings on diabetes?

Diabetes is a condition where a person has higher blood sugar than normal. It is either caused by a failure of the pancreas to produce insulin (ie type 1, or insulin-dependent diabetes mellitus), or resistance of the body's cells to insulin present in the circulation (ie type 2, or non-insulin-dependent diabetes mellitus). There are also other disorders of the pancreas. Inflammation of the organ (ie acute pancreatitis) causes severe pain in the upper abdomen, forcing most people to attend the emergency department as it can actually be life threatening. In contrast, cancer of the pancreas causes the individual gradually worsening pain which can commonly be mistaken for various other ailments.



Does the pancreas vary in humans and animals?

Every vertebrate animal has a pancreas of some form, meaning they are all susceptible to diabetes too. The arrangement, however, varies from creature to creature. In humans, the pancreas is most often a single structure that sits at the back of the abdomen. In other animals, the arrangement varies from two or three masses of tissue scattered around the abdomen, to tissue interspersed within the connective tissue between the bowels, to small collections of tissue within the bowel mucosal wall itself. One of the other key differences is the number of ducts that connect the pancreas to the bowel. In most humans there's only one duct, but occasionally there may be two or three – and sometimes even more. In other animals, the number is much more variable. However, the function is largely similar, where the pancreas secretes digestive enzymes and hormones to control blood sugar levels.

The urinary system explained

Every day the body produces waste products that enter the bloodstream – but how do we get rid of them?

The human urinary system's primary function is to remove by-products which remain in the blood after the body has metabolised food. The process is made up of several different key features. Generally, this system consists of two kidneys, two ureters, the bladder, two sphincter muscles (one internal, one external) and a urethra and these work alongside the intestines, lungs and skin, all of which excrete waste products from the body.

The abdominal aorta is an important artery to the system as this feeds the renal artery and vein, which supply the kidneys with blood. This blood is filtered by the kidneys to remove waste products, such as urea which is formed through amino acid metabolism. Through communication with other areas of the body, such as the hypothalamus, the kidneys also control water levels in the body, sodium and potassium levels among other electrolytes, blood pressure, pH of the blood and are also involved in red blood cell production through the creation and release of the hormone erythropoietin. Consequently, they are absolutely crucial to optimum body operation.

After blood has been filtered by the kidneys, the waste products then travel down the ureters to the bladder. The bladder's walls expand out to hold the urine until the body can excrete the waste out through the urethra. The internal and external sphincters then control the release of urine.

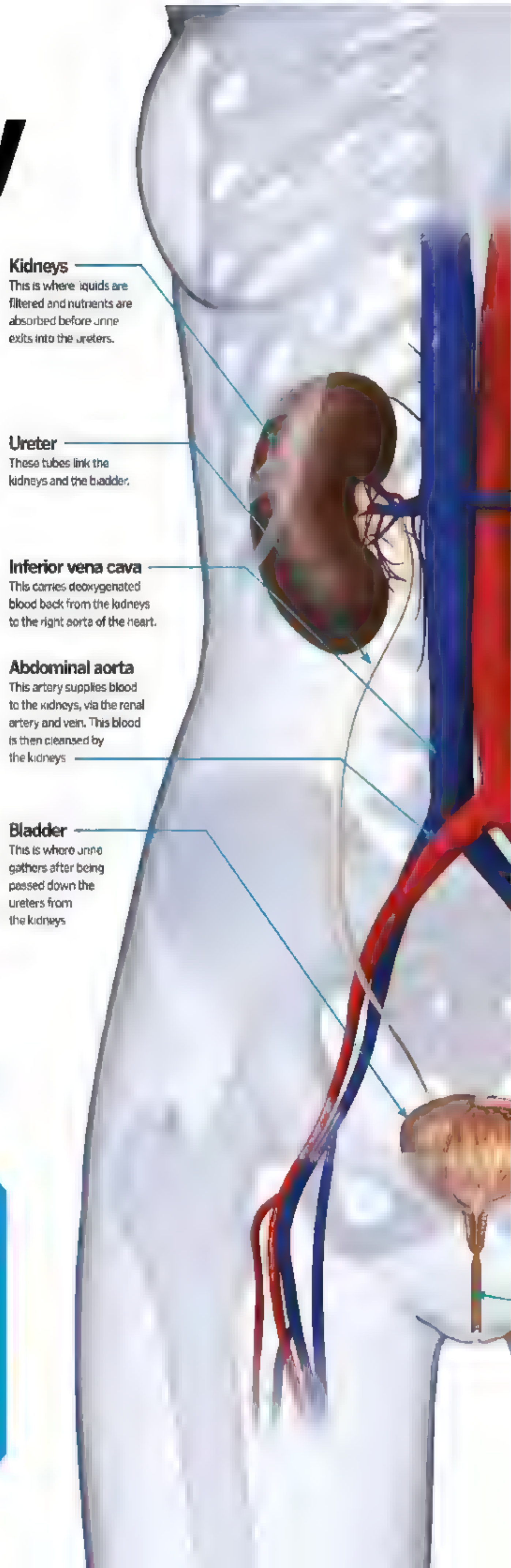
On average, a typical human will produce approximately a staggering 2.5-3 litres of urine in just one day, although this can vary dramatically dependant on external factors such as how much water is consumed.

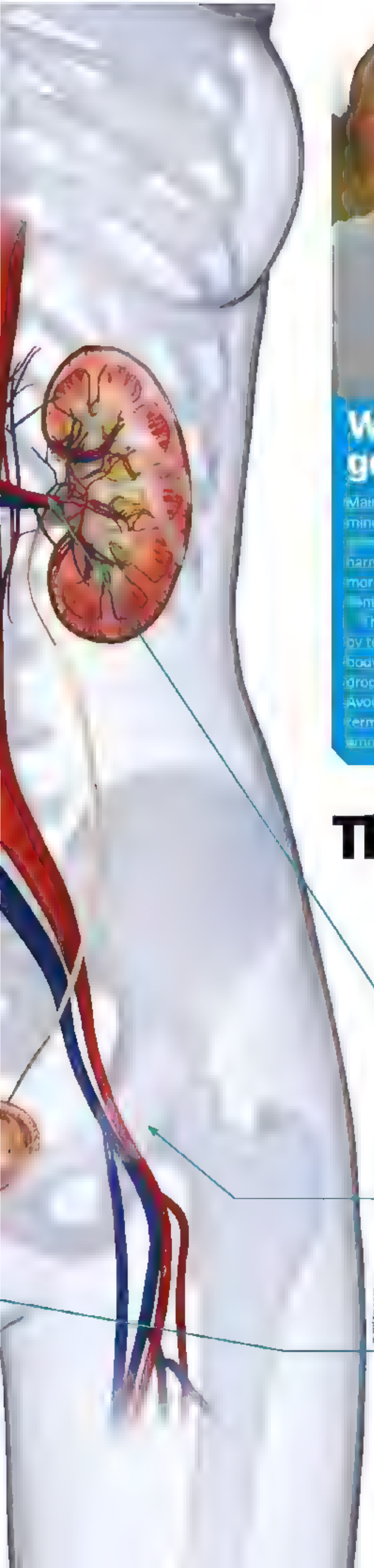
"Generally, a human will produce 2.5-3 litres of urine a day"

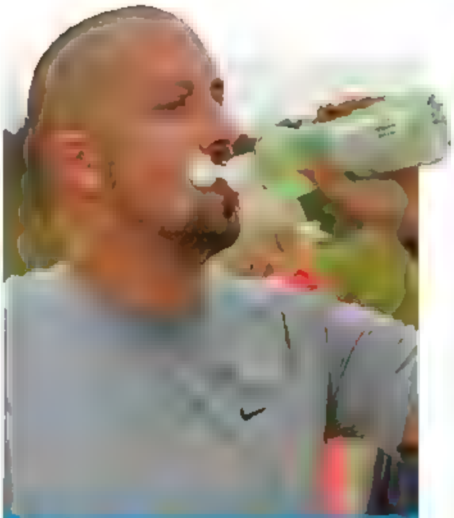
How do the kidneys work?

The kidneys will have around [illegible]0-180 litres of blood to filter per day, but only pass around two litres of waste dow[illegible] the ureters to the bladder for excretion, therefore [illegible] kidneys return much of this blood [illegible] minus mos[illegible] of the waste products, to the [illegible]rt for re-oxygenation and recirculation around the body.

The way the kidneys do this is to pass the blood through a small filtering unit [illegible]alled a nephron. Each kidney has ar[illegible]d a million of these [illegible]h are made up of [illegible] number o[illegible]ll blood capillaries and [illegible]e called the renal tubule. The blood [illegible]pillaries sift the normal [illegible]ls and pro[illegible] from the blood for recirculation and [illegible]en direct the was[illegible] products into the [illegible]nal tubule. This waste, which wi[illegible] orim[illegible]ater and forms urin[illegible]t passes throug[illegible] [illegible] tubule and [illegible] on its way to the bladder.







Why do we get thirsty?

Maintaining the balance between the minerals and salts in our body and water is very important. When this is out of harmony, the body tells us to consume more liquids in order for the body to continue operating effectively.

This craving, or thirst, can be caused by too high a concentration of salts in the body, or by the water volume in the body dropping too low for optimal operation. Avoiding dehydration is important as long term dehydration can cause renal failure among other conditions.

The human urinary system

Renal artery and vein
This supplies blood to the kidneys in order for them to operate, and then removes deoxygenated blood after use by the kidneys.

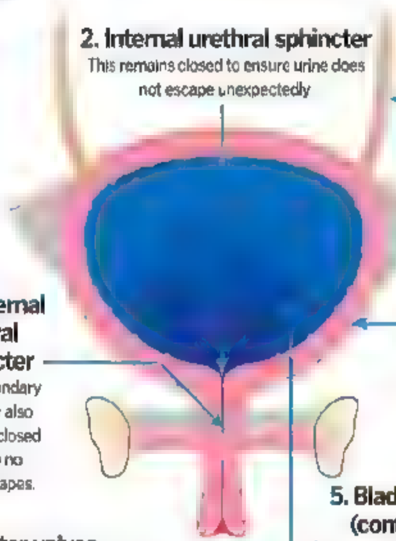
Pelvis
The bladder sits in the pelvis, and the urethra passes through it for urine to exit the body.

Urethra
The urethra is the tube that urine travels through to exit the body.

How do we store waste until we're ready to expel it?

The bladder stores waste products by allowing the urine to enter through the ureter valves, which attach the ureter to the bladder. The walls relax as urine enters and this allows the bladder to stretch. When the bladder becomes full, the nerves in the bladder communicate with the brain and cause the individual to feel the urge to urinate. The internal and external sphincters will then relax, allowing urine to pass down the urethra.

Bladder fills



1. Ureters
These tubes connect to the kidneys and urine flows down to the bladder through them.

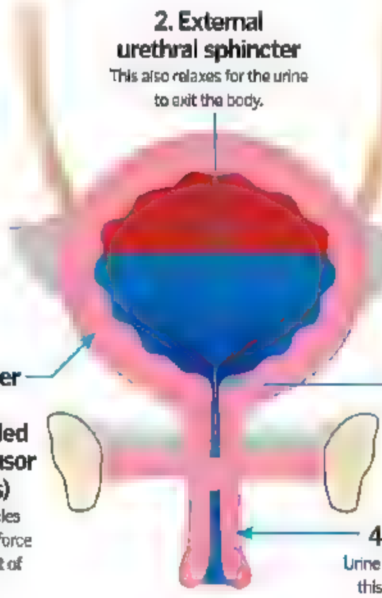
2. Internal urethral sphincter
This remains closed to ensure urine does not escape unexpectedly.

3. External urethral sphincter
This secondary sphincter also remains closed to ensure no urine escapes.

4. Ureter valves
These valves are situated at the end of the ureters and let urine in.

5. Bladder walls (controlled by detrusor muscles)
The detrusor muscles in the wall of the bladder relax to allow expansion of the bladder as necessary.

Bladder empties



1. Internal urethral sphincter
This relaxes when the body is ready to expel the waste.

2. External urethral sphincter
This also relaxes for the urine to exit the body.

3. Bladder walls (controlled by detrusor muscles)
These muscles contract to force the urine out of the bladder.

4. Urethra
Urine travels down this passageway to exit the body.

How the Body Works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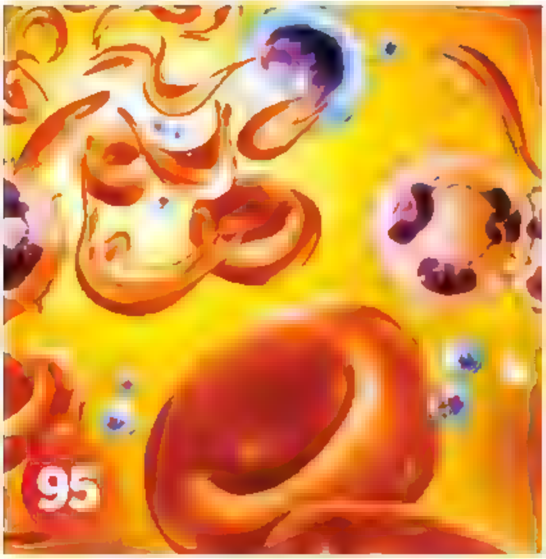
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The science of Sleep

Unravelling the mysteries behind insomnia, sleepwalking, dreams and more

We spend around a third of our lives sleeping. It is vital to our survival, but despite years of research, scientists still aren't entirely sure why we do it. The urge to sleep is all-consuming, and if we are deprived of it, we will eventually slip into slumber even if the situation is life-threatening.

Sleep is an essential habit to mammals, birds and reptiles and has been conserved through evolution, despite preventing us from performing tasks such as eating, reproducing and raising young. It is as important as food and, without it, rats will die within two or three weeks – the same period it takes to die of starvation.

There have been many ideas and theories proposed about why humans sleep, from a way to rest after the day's activities or a method for saving energy, to simply a way to fill time until we can be doing something useful. But all of these ideas are somewhat flawed. The body repairs itself just as well when we are sitting quietly, we only save around 100 calories a night by sleeping, and we wouldn't need to catch up on sleep during the day if it were just to fill empty time at night.

One of the major problems with sleep deprivation is a resulting decline in cognitive ability – our brains just don't work properly without sleep. We will find ourselves struggling with memory, learning,

Theories of why we sleep

Theory 1

Energy conservation

We save around 100 calories per night by sleeping; metabolic rate drops, the digestive system is less active, heart and breathing rates slow, and body temperature drops. However, the calorie-saving equates to just one cup of milk, which from an evolutionary perspective does not seem worth the accompanying vulnerability.

Theory 3

Restoration

One of the major problems with sleep deprivation is a decline in cognitive function, accompanied by a drop in mood, and there is mounting evidence that sleep is involved in restoring the brain. However, there is little evidence to suggest that the body undergoes more repair during sleep compared to rest or relaxation.

Theory 2

Evolutionary protection

An early idea about the purpose of sleep is that it is a protective adaptation to fill time. For example, prey animals with night vision might sleep during the day to avoid being spotted by predators. However this theory cannot explain why sleep-deprived people fall asleep in the middle of the day.

Theory 4

Memory consolidation

One of the strongest theories regarding sleep is that it helps with consolidation of memory. The brain is bombarded with more information during the day than it is possible to remember, so sleep is used to sort through this information and selectively practise parts that need to be stored.

planning and reasoning. A lack of sleep can actually have severe effects on our mood and performance of everyday tasks, ranging from irritability, through to long term problems such as an increased risk of heart disease and even a higher incidence of road traffic accidents.

Sleep can be divided into two broad stages: non-rapid eye movement (NREM), and rapid eye movement (REM) sleep. The vast majority of our sleep, actually around 75 to 80 per cent of it, is NREM, which is characterised by various electrical patterns in the brain known as 'sleep spindles' and high, slow delta waves. When this is occuring, this is the time when we sleep the deepest.

Without NREM sleep, our ability to form declarative memories, such as learning to associate pairs of words, can be seriously impaired. Deep sleep is important for transferring short-term memories into long-term storage. Deep sleep is also the time of peak growth hormone release in the body, which is important for cell reproduction and repair.

The purpose of REM sleep is unclear, with the effects of REM sleep deprivation proving less severe than NREM deprivation; for the first two weeks humans report little in the way of ill effects. REM sleep is the period during the night when we have our most vivid dreams, but people dream during both NREM and REM sleep. One curiosity is that during NREM sleep, dreams tend to be more concept-based, whereas REM sleep dreams are a lot more vivid and emotional.

Some scientists argue that REM sleep allows our brains a safe place to practice dealing with situations or emotions that we might not encounter during our daily lives. During REM sleep our muscles are temporarily paralysed, preventing us acting out these emotions. Others think that it might be a way to unlearn memories, or to process unwanted feelings or emotions. Each of these ideas has its flaws, and no one knows the real answer.

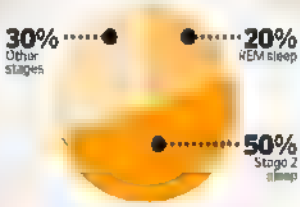
We will delve into the science of sleep and attempt to make sense of the mysteries of the sleeping brain.

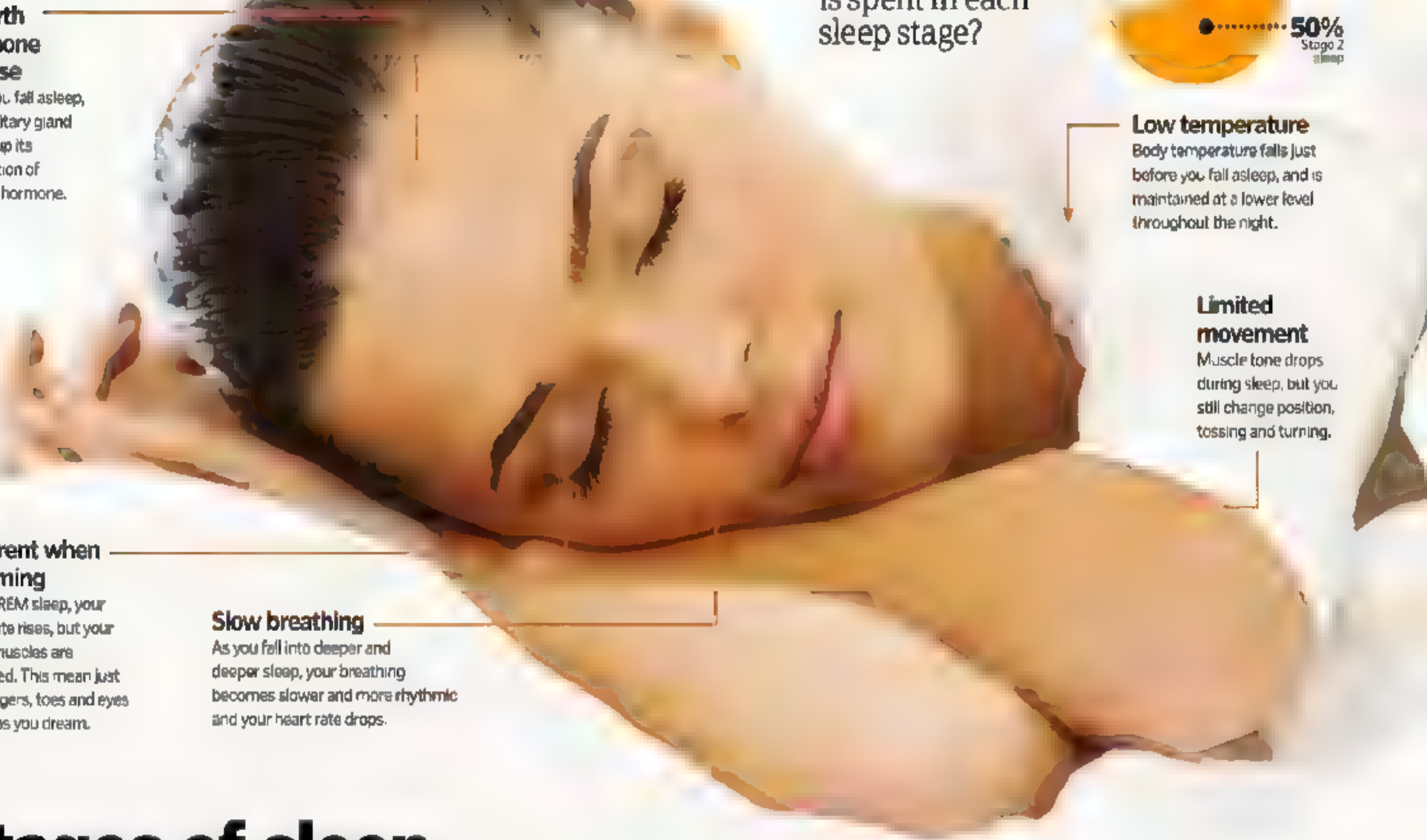
The sleep cycle

In the night, you cycle through five separate stages of sleep every 90 to 110 minutes

The five stages of sleep can be distinguished by changes in the electrical activity in your brain, measured by electroencephalogram (EEG). The first stage begins with drowsiness as you drift in and out of consciousness, and is followed by light sleep and then by two stages of deep sleep. Your brain activity starts to slow down, your breathing, heart rate and temperature drop, and you become progressively more difficult to wake up. Finally, your brain perks up again, resuming activity that looks much more like wakefulness, and you enter rapid eye movement (REM) sleep – the time when your most vivid dreams occur. This cycle happens several times throughout the night, and each time, the period of REM sleep grows longer.

How much time is spent in each sleep stage?





Growth hormone release
After you fall asleep, the pituitary gland ramps up its production of growth hormone.

Low temperature
Body temperature falls just before you fall asleep, and is maintained at a lower level throughout the night.

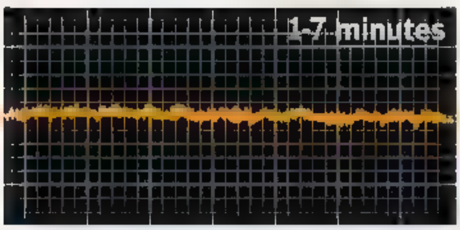
Limited movement
Muscle tone drops during sleep, but you still change position, tossing and turning.

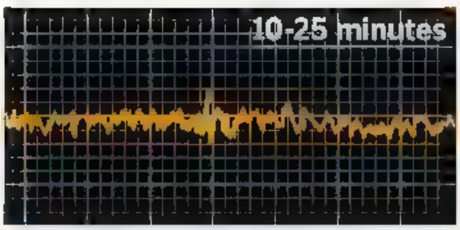
Different when dreaming
During REM sleep, your heart rate rises, but your larger muscles are paralysed. This mean just your fingers, toes and eyes twitch as you dream.

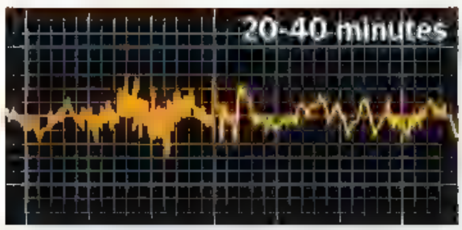
Slow breathing
As you fall into deeper and deeper sleep, your breathing becomes slower and more rhythmic and your heart rate drops.

Stages of sleep

Not all sleep is the same. There are five separate stages, divided by brain activity







1 Drowsiness

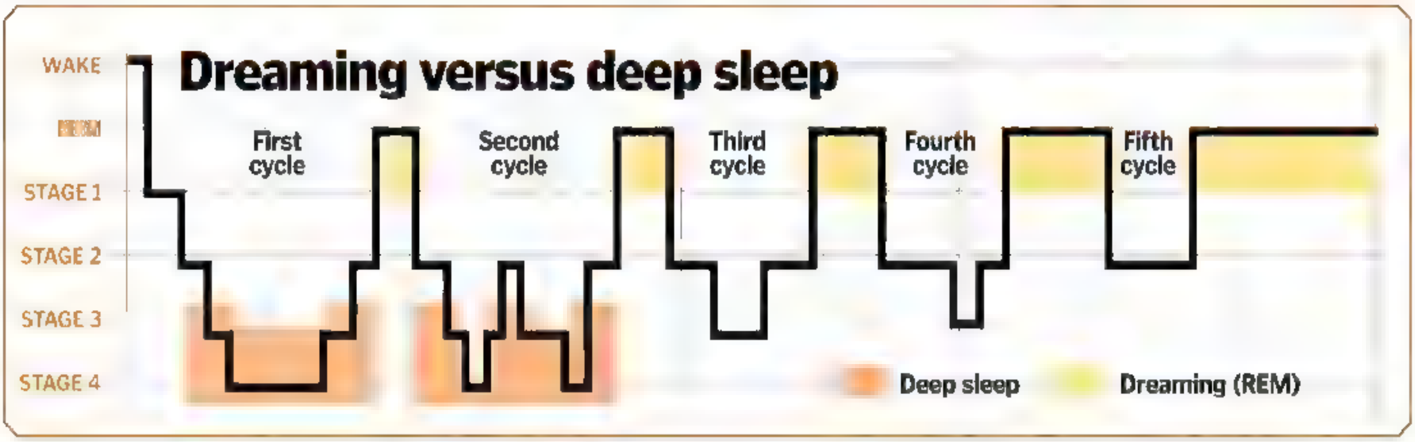
In the first stage, you drift off, your eyelids are heavy and your head starts to drop. During this drowsy period, you are easily woken and your brain is still quite active. The electrical activity on an electroencephalogram (EEG) monitor starts to slow, and cortical waves become taller and spikier. As the sleep cycle repeats during the night, you re-enter this drowsy half-awake, half-asleep stage.

2 Light sleep

After a few minutes, your brain activity slows further, and you descend into light sleep. On the EEG monitor, this stage is characterised by further slowing in the waves, with an increase in their size and short one- or two-second bursts of activity known as 'sleep spindles'. By the time you are in the second phase of sleep, your eyes stop moving, but you can still be woken up quite easily.

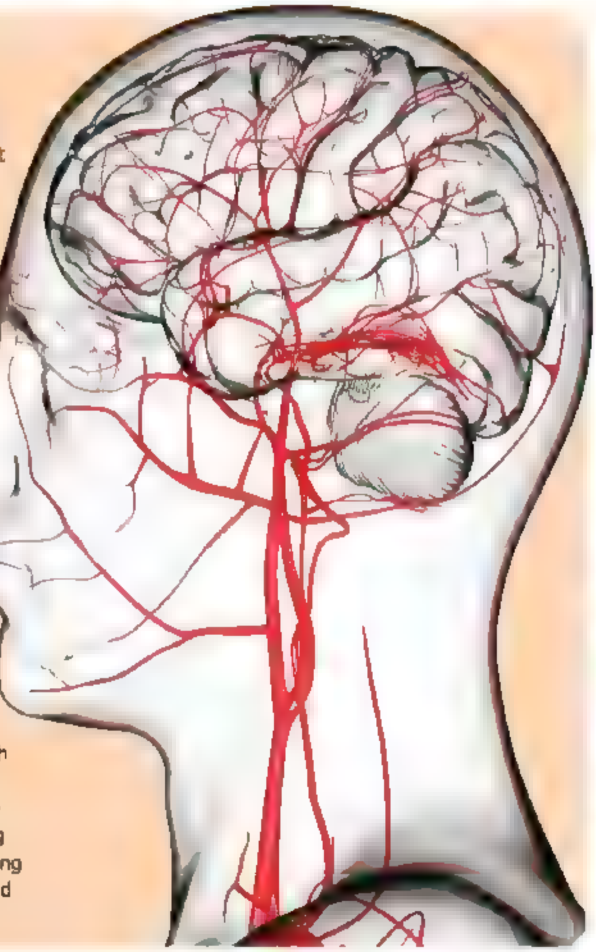
3 Moderate sleep

As you start to enter this third stage, your sleep spindles stop, this in turn is showing that your brain has entered moderate sleep. This is then followed by deep sleep. The trace on the EEG slows still further as your brain produces delta waves with occasional spikes of smaller, faster waves in between. As you progress through stage-three sleep, you become much more difficult to wake up.

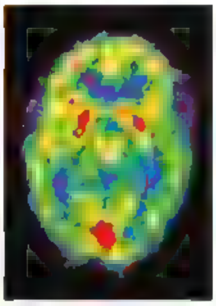


Clearing the mind

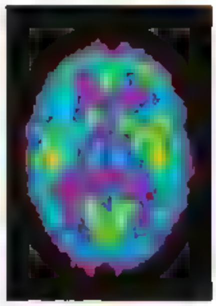
The brain is a power-hungry organ; it makes up only two per cent of the total mass of the body, but it uses an enormous 25 per cent of the total energy supply. The question is, how does it get rid of waste? The Nedergaard Lab at the University of Rochester in New York thinks sleep might be a time to clean the brain. The rest of the body relies on the lymphatic drainage system to help remove waste products, but the brain is a protected area, and these vessels do not extend upward into the head. Instead, your central nervous system is bathed in a clear liquid called cerebrospinal fluid (CSF), into which waste can be dissolved for removal. During the day, it remains on the outside, but the lab's research has shown that, during sleep, gaps open up between brain cells and the fluid rushes in, following paths along the outside of blood vessels, sweeping through every corner of the brain and helping to clear out toxic molecules.



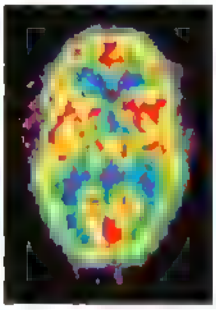
Brain activity



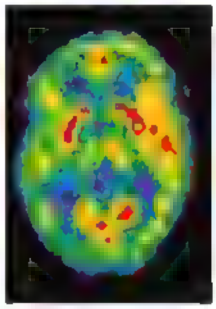
Wide awake
The red areas in this scan show areas of activity in the waking human brain, while the blue areas represent areas of inactivity.



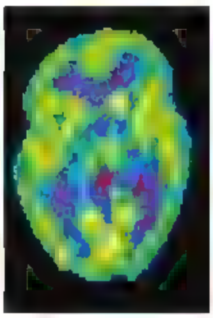
Deep sleep
During the later stages of NREM sleep, the brain is less active, shown here by the cool blue and purple colours that dominate the scan.



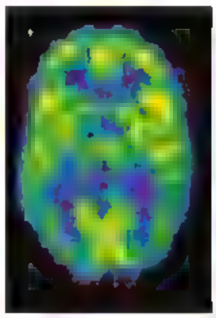
REM (dream) sleep
When we are dreaming, the human brain shows a lot of activity, displaying similar red patterns of activity to the waking brain.



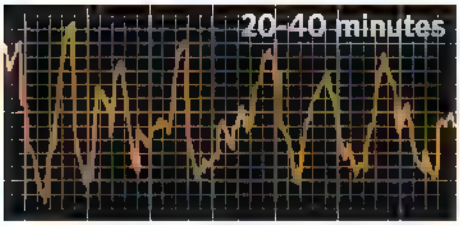
Light sleep
In the first stages of NREM sleep, the brain is less active than when awake, but you remain alert and easy to wake up.



Sleep deprivation
The sleep-deprived brain looks similar to the brain during NREM sleep, showing patterns of inactivity.

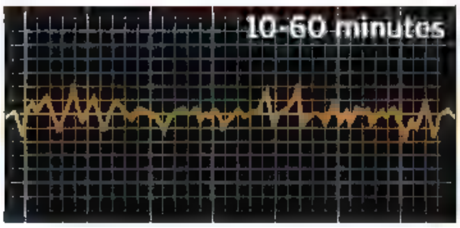


NREM sleep
As you descend through the four stages of NREM sleep, your brain in turn becomes progressively less active.



4 Deep sleep

There is some debate as to whether sleep stages three and four are really separate, or whether they are part of the same phase of sleep. Stage four is the deepest stage of all, and during this time you are extremely hard to wake. The EEG shows tall, slow waves which are known as delta waves; your muscles will relax and your breathing becomes slow and rhythmic, which can lead to snoring.



5 REM sleep

After deep sleep, your brain starts to perk up and its electrical activity starts to resemble the waking brain. This is the period of the night when most dreams happen. Your muscles are temporarily paralysed, and your eyes dart around, giving it the name rapid eye movement (REM) sleep. You cycle through the stages of sleep every 90 minutes, experiencing between three and five dream periods each night.

Sleep disorders

There are over 100 different disorders that prevent a good night's sleep

Sleep is necessary for our health, so disruptions to the quality or quantity of our sleep can have a serious negative impact on daily life, affecting both physical health and mental wellbeing.

Sleep disorders fall into four main categories: difficulty falling asleep, difficulty staying awake, trouble sticking to a regular sleep pattern and abnormal sleep behaviours. Struggling with falling asleep or staying asleep is known as insomnia, and is one of the most familiar sleep disorders; around a third of the population will experience it during their lifetime. Difficulty staying awake, or hypersomnia, is less common. The best-known example is narcolepsy, which is when sufferers experience excessive daytime sleepiness, accompanied by uncontrollable short periods of sleep during the day. Trouble sticking to a regular sleeping pattern can either be caused by external disruption to normal day-to-day rhythms, for example by jet lag or shift work. It can also be the result of an internal problem with the part of the brain responsible for setting the body clock.

Abnormal sleep behaviours include problems like night terrors, sleepwalking and REM-sleep behaviour disorder. Night terrors and sleepwalking most commonly affect children, and tend to resolve themselves with age, but other sleep behaviours persist into adulthood. In REM-sleep behaviour disorder, the normal muscle paralysis that accompanies dreaming fails, and people begin to act out their dreams.

Treatment for different sleep disorders varies depending on the particular problem, and sometimes it can even be as simple as making the individuals bedroom environment more conducive to restful sleep.

A continuous positive airway pressure (CPAP) machine pumps air into a close-fitting mask, preventing the airway from collapsing

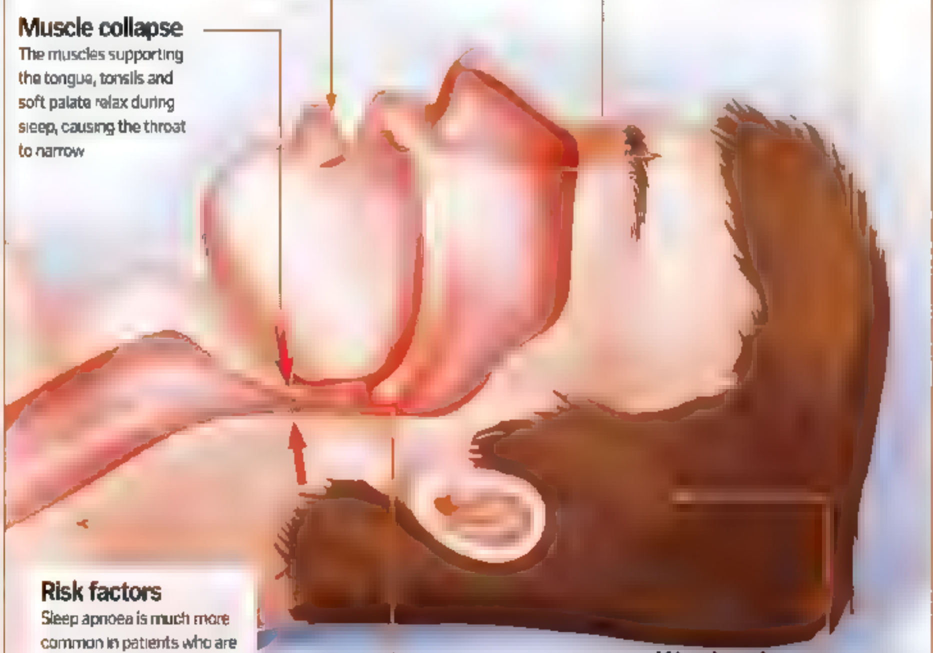
Sleepwalking

Sleepwalking affects between one and 15 per cent of the population, and is much more common in children than in adults, tending to happen less and less after the age of 11 or 12. Sleepwalkers might just sit up in their bed, but can sometimes perform complex behaviours, such as walking, getting dressed, cooking, or even driving a car. Although sleepwalkers seem to be acting out their dreams, sleepwalking tends to occur during the deep-sleep phase of NREM sleep, and not during REM sleep.

Sleepwalkers can perform complicated actions while in deep NREM sleep

Sleep apnoea

Sleep apnoea is a dangerous sleep disorder. It is when the walls of the airways relax so much during the night that breathing is interrupted for ten seconds or more, restricting the supply of oxygen to the brain. The lack of oxygen initiates a protective response, pulling the sufferer out of deep sleep to protect them from damage. This can cause people to wake up, but often it will just put them into a different sleep stage, interrupting their rest and causing them to feel tiredthe next day. Sleep apnoea should be treated before it leads to further problems.



Loud breathing
People suffering with sleep apnoea often snore, gasp and breathe loudly as they struggle for air during the night.

Waking up
The low oxygen level in the blood triggers the brain to wake up in an attempt to fix the obstruction.

Lack of oxygen
If the airway is obstructed for ten seconds or more, the amount of oxygen reaching the brain drops.

Muscle collapse
The muscles supporting the tongue, tonsils and soft palate relax during sleep, causing the throat to narrow

Risk factors
Sleep apnoea is much more common in patients who are overweight, male and over the age of 40. Smoking, alcohol and sleeping pills also increase the risk.

Reduced airflow
Soft-tissue collapse reduces the amount of air entering the lungs or obstructing the airways completely.

Warning signs
People may not know they have sleep apnoea, but warning signs include daytime sleepiness, headaches and night sweats.

Narcolepsy

Narcolepsy is a chronic condition that causes people to suddenly fall asleep during the daytime. In the United States, it affects one in every 3,000 people. Narcoleptics report excessive amounts of daytime sleepiness, accompanied by a lack of energy and impaired ability to concentrate. They fall asleep involuntarily for periods lasting just a few seconds at a time, and some can continue to perform tasks such as writing, walking, or even driving during these microsleeps. In 70 per cent of cases, narcolepsy is also accompanied by cataplexy, where the muscles go limp and become difficult to control. It has been linked to low levels of the neurotransmitter hypocretin, which is responsible for promoting wakefulness in the brain.

People with narcolepsy ... during the day

Insomnia

Insomniacs have difficulty falling asleep or staying asleep. Sufferers can wake up during the night, wake up unusually early in the morning, and report feeling tired and drained during the day. Stress is thought to be one of the major causes of this sleep disruption, but it is also associated with mental health problems like depression, anxiety and psychosis, and also with underlying medical conditions that range from lung problems to hormone imbalances. After underlying causes have been ruled out, management of insomnia generally involves improving 'sleep hygiene' by sticking to regular sleep patterns, avoiding caffeine in the evening and keeping the bedroom free from light and noise at night.

One in three people in the UK will experience insomnia in their lifetime

Sleep studies

Electrodes monitor brain activity, eye movement, heart rate and breathing in sleep studies

© BSIP SA / Alamy

How to get a good night's sleep

Understanding your biological clock is the key to a healthy night's sleep

Your body is driven by an internal circadian master clock known as the suprachiasmatic nucleus, which is set on a time scale of roughly 24 hours. This biological clock is set by sunlight; blue light hits special receptors in your eyes, which feed back to the master clock and on to the pineal gland. This suppresses the production of the sleep hormone melatonin and tells your brain that it is time to wake up.

Disruptions in light exposure can play havoc with your sleep, so it is important to ensure that your bedroom is as dark as possible. Many electronic devices produce enough light to reset your biological clock, and using backlit screens late at night can confuse your brain, preventing the production of melatonin and delaying your sleep.

Ensuring you see sunlight in the morning can help to keep your circadian clock in line, and sticking to a regular sleep schedule, even at the weekends, helps to keep this rhythm regular.

Another important factor in a good night's sleep is the process of winding down before bed. Certain stimulants such as caffeine and nicotine will actually keep your brain alert and can seriously disrupt your attempts to sleep. Even depressants like alcohol can have a negative effect; even though it calms the brain, it interferes with normal sleep cycles, preventing proper, restorative, deep and REM sleep.

The blue light from televisions, mobile phones and computer screens disrupts your circadian rhythm

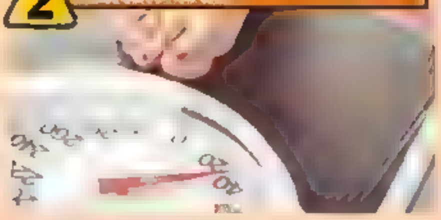
The dangers of sleep deprivation

Lack of sleep doesn't just make you tired – it can have dangerous unseen effects

1 IMPAIRED JUDGEMENT

Sleep deprivation impacts your visual working memory, making it hard to distinguish between relevant and irrelevant stimuli, affecting emotional intelligence, behaviour and stress management.

2 WEIGHT GAIN



Sleep deprivation affects the levels of hormones involved in regulating appetite. Levels of leptin (the hormone that tells you how much stored fat you have) drop, and levels of the hunger hormone ghrelin rise.

3 [illegible]

Poor sleep can raise blood pressure, and in the long term is associated with an increased risk of diseases such as coronary heart disease and stroke. This danger is increased in people with sleep apnoea.

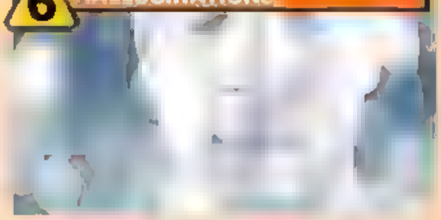
4 INCREASED ACCIDENTS

In the USA it is estimated that 100,000 road accidents each year are the result of driver fatigue, and over a third of drivers have even admitted to falling asleep behind the wheel.

5 [illegible]

Mental health problems are linked to sleep disorders, and having sleep deprivation can play havoc with neurotransmitters in the brain, mimicking the symptoms of depression, anxiety and mania.

6 HALLUCINATIONS



Severe sleep deprivation can lead to hallucinations – seeing things that aren't really there. In rare cases, it can lead to temporary psychosis or symptoms that resemble paranoid schizophrenia.

Sleep myths debunked

The science behind five of the most common myths relating to sleep

"Counting sheep helps you sleep"

This myth was put to the test by the University of Oxford, who challenged insomniacs to either count sheep, imagine a relaxing scene, or do nothing as they tried to fall asleep. When they imagined a relaxing scene, the participants fell asleep an average of 20 minutes earlier than when they tried either of the other two methods.

"Yawning wakes you up"

Yawning has long been associated with tiredness and was fabled to provide more oxygen to a sleepy brain, but this is not the case. New research suggests that we actually yawn to cool our brains down, using a deep intake of breath to keep the brain running at its optimal temperature.

"Teenagers are lazy"

Sleep habits start to change just before puberty, and between the ages of ten and 25, people need around nine hours of sleep every night. Teens can also experience a shift in their circadian rhythm, called sleep phase delay, pushing back their natural bedtime by around two hours, and encouraging them to sleep in.

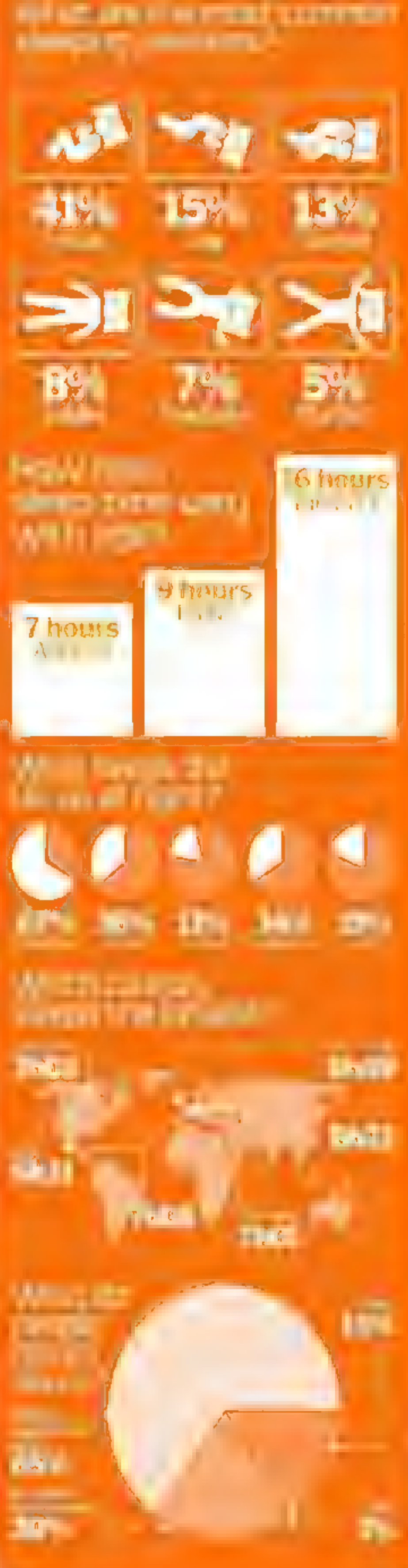
"You should never wake a sleepwalker"

Many people have heard that waking a sleepwalker might kill them, but there is little truth behind these tales. Waking a sleepwalker can leave them confused and disorientated, but the act of sleepwalking in itself can be much more dangerous. Gently guiding a sleepwalker back to their bed is the safest option, but waking them carefully shouldn't do any harm.

"Cheese gives you nightmares"

The British Cheese Board conducted a study in an attempt to debunk this myth by feeding 20g (0.7oz) of cheese to 200 volunteers every night for a week and asking them to record their dreams. There were no nightmares, but strangely 75 per cent of men and 85 per cent of the women who ate Stilton reported vivid dreams.

SLEEP STATS



Neurotransmitters and your feelings

Are our moods and emotions really just brain chemistry?

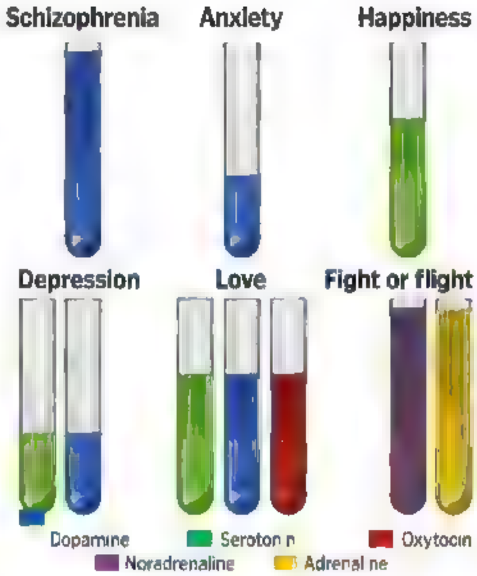
Messages are passed from one nerve cell to the next by chemical messengers called neurotransmitters. Each has a slightly different effect and by looking at what happens when neurotransmitter levels change, we are discovering that different combinations play a role in a range of complex emotions.

Acetylcholine excites the nerve cells that it touches, triggering more electrical activity. It plays a role in wakefulness, attention, learning and memory, and abnormally low levels are found in the brains of people with dementia caused by Alzheimer's disease.

Dopamine is a chemical that also excites nerve cells. It plays a vital role in the control of movement and posture, and low levels of dopamine underlie the muscle rigidity that exists in Parkinson's disease. Dopamine is also used in the brain's reward circuitry and is one of the chemicals responsible for the good feelings that are normally associated with more addictive behaviour types.

Noradrenaline is similar in structure to the hormone adrenaline and is involved in the 'fight or flight' response. In the brain, it keeps us alert and focussed. In contrast, GABA reduces the activity of the nerves that it interacts with and is thought to reduce feelings of fear or anxiety.

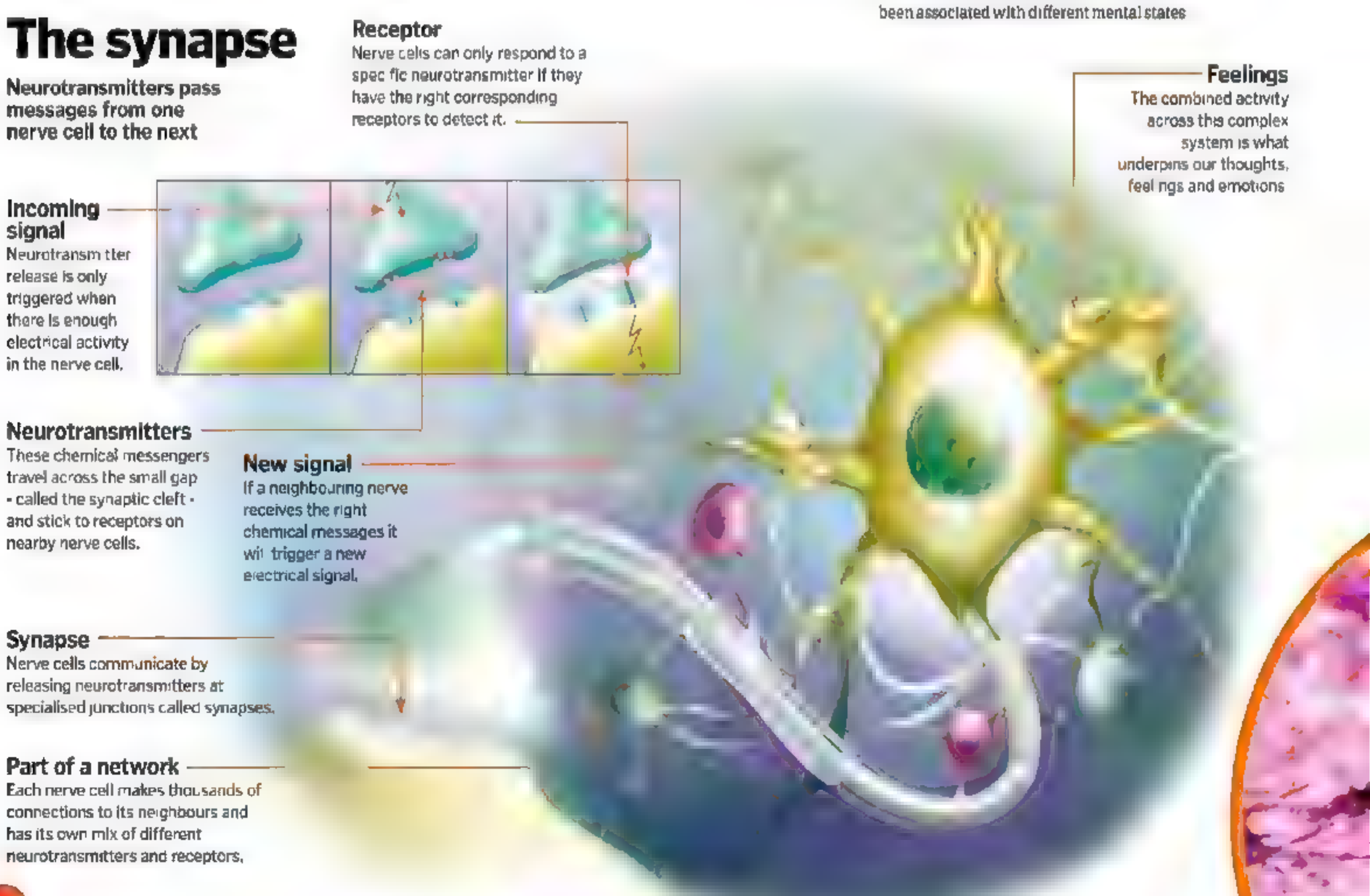
Serotonin is sometimes known as the 'happy hormone' and transmits signals involved in body temperature, sleep, mood and pain. People with depression have been found to have lower serotonin levels than normal, though raising serotonin levels with antidepressant medications does not always help. There are many more neurotransmitters in the brain and other chemicals like hormones can also influence the behaviour of nerve cells. It is these interactions that are thought to underlie the huge range of human emotions.



Different levels of neurotransmitters have been associated with different mental states

The synapse

Neurotransmitters pass messages from one nerve cell to the next



Brain cells

Find out what's really going on inside your head

Your brain is an incredible thing. It is one of the most complex structures in the known universe, and for decades, scientists have been teasing it apart to find out what it's made of and how it works.

The brain is an electrical and chemical circuit, and nerve cells, or neurons, are the components. They each have a cell body, which contains their genetic code, an axon to transmit electrical impulses, and dendrites to receive them.

They are connected together at junctions known as synapses. When an impulse arrives, packets of molecules are released, passing the message on. Each neuron makes hundreds, or even thousands, of connections, producing the complicated patterns that drive human thought.

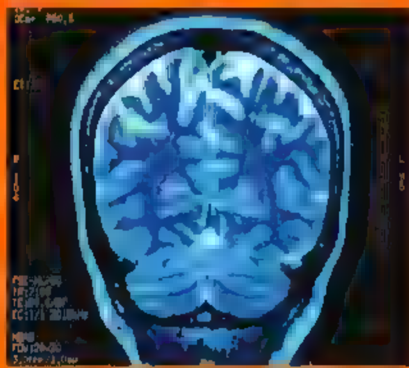
There are hundreds of different types of neuron in the brain, categorised according to their unique structure and function, and more are being discovered all the time. But they can't function on their own. They are supported by a network of glial cells – a name that literally means 'glue'.

There are three main types of glial cell. Oligodendrocytes have fatty branches, which they wrap around the conducting axons of nerve cells like the plastic coating on electrical wires. This provides insulation, preventing signals from getting crossed and speeding up their transmission along the chain.

Microglia are part of the immune system and act like an in-house cleanup crew, tracking down pathogens and clearing debris from the brain. Then there's the star-shaped astrocytes, which reach between nerve cells and blood vessels with their long, thin arms, shuttling nutrients, mopping up waste products, and even getting involved with chemical signalling.

How many cells?

... the brain. Individual neurons have long ... ns and branching trees of dendrites ... forming a tangled mass that is almost ...



Different parts of the ...

Under the microscope

A closer look at the brain reveals a complex network of different cells

Neuron
These are the nerve cells, responsible for transmitting and receiving the electrical and chemical signals in the brain.

Dendrite
These branching processors receive thousands of incoming signals from other neurons.

Microglia
These are specialist immune cells, helping to keep the brain healthy and free from disease.

Oligodendrocyte
These cells provide insulation, wrapping fatty membranes around the neurons to speed up their electrical signals.

Astrocyte
These star-shaped cells support the neurons, providing nutrients, clearing waste and contributing to signalling.

Axon
This part of the neuron transmits electrical signals towards neighbouring cells.

Synapse
Chemical signals are exchanged at these junctions, passing messages from one neuron to the next.

This microscope image shows astrocytes grabbing on to blood vessels with their 'feet'

Human digestion

How does food get turned into energy?

The digestive system is a group of organs that process food into energy that the human body can use to operate. It is an immensely complex system that stretches all the way between the mouth and the anus. Primary organs that make up the system are the mouth, oesophagus, stomach, small intestine, large intestine and the anus. Each organ has a different function so that the maximum amount of energy is gained from the food, and the waste can be safely expelled from the body. Secondary organs, such as the liver, pancreas and gall bladder, aid the digestive process alongside mucosa cells, which line all hollow organs and produce a secretion which helps the food pass smoothly through them. Muscle contractions called peristalsis also help to push the food throughout the system.

The whole digestive process starts when food is taken into the body through the mouth. Mastication (chewing) breaks down the food into smaller pieces and saliva starts to break starch in these pieces of food into simpler sugars as they are swallowed and move into the oesophagus. Once the food has passed through the oesophagus, it passes into the stomach. It can be stored in the stomach for up to four hours.

The stomach will eventually mix the food with the digestive juices that it produces, which will break down the food further into simpler molecules. These molecules then move into the small intestine slowly, where the final stage of chemical breakdown occurs through exposure to juices and enzymes released from the pancreas, liver and glands in the small intestine. All the nutrients are then absorbed through the intestinal walls and transported around the body through the blood stream.

After all nutrients have been absorbed from food through the small intestine, resulting waste material, including fibre and old mucosa cells, is then pushed into the large intestine where it will remain until expelled by a bowel movement.

"Nutrients are then absorbed through the intestinal walls and transported around the body"

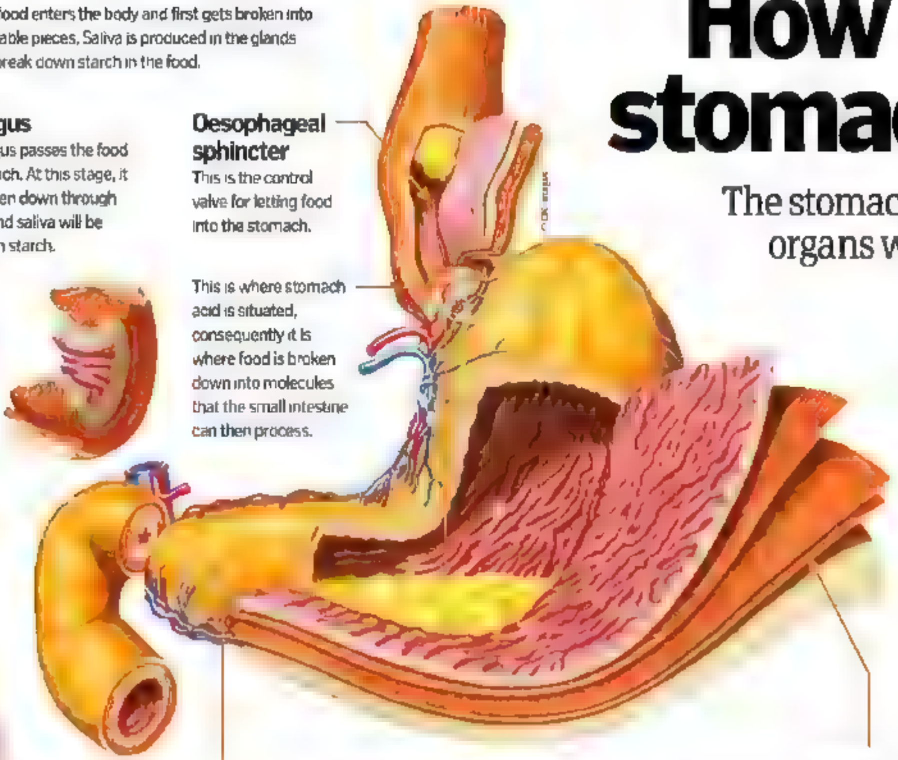
How your body digests food

Many different organs are involved in the digestion process

How does our stomach work?

The stomach is one of the most crucial organs within the digestive system

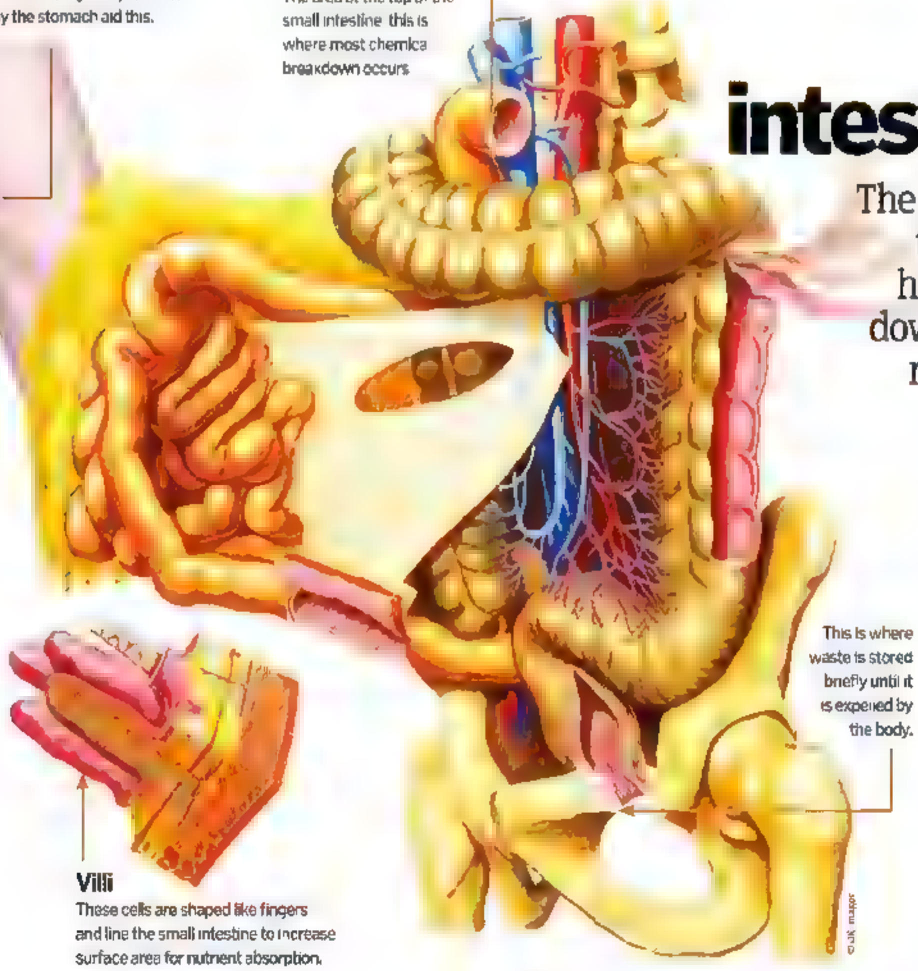
The stomach's function is to break down food into simple molecules before it moves into the small intestine where nutrients are absorbed. The organ actually splits into four distinct parts, all of which have different functions. The uppermost section is the cardia, where food is first stored after ingesting it, the fundus is the area above the corpus body, which makes up the main area of the stomach where ingested food is mixed with stomach acid. The final section is the antrum, containing the pyloric sphincter, which is in control of emptying the stomach contents into the small intestine. Food is automatically passed down into the stomach by mucosa and peristalsis through the oesophageal sphincter, and then mixed in the stomach with acids and juices by automatic muscle contractions.



How the intestine works

The intestine is a crucial part of the digestive system that is heavily involved in breaking down and absorbing nutrients released from ingested food

The intestine splits into two distinct parts, the small intestine and the large intestine. The small intestine is where the food goes through final stages of digestion and nutrients are absorbed into the blood stream, the large intestine is where waste is stored until expelled through the anus. Both the small and large intestines can be further divided into sections, the duodenum, jejunum and ileum are the three distinct sections of the small intestine and the cecum, colon and rectum are the sections of the large intestine. As well as storing waste, the large intestine removes water and salt from the waste before it is expelled. Muscle contractions and mucosa are essential for the intestine to work properly, and we see a variation of mucosa, called villi, present in the lower intestine.



Human respiration

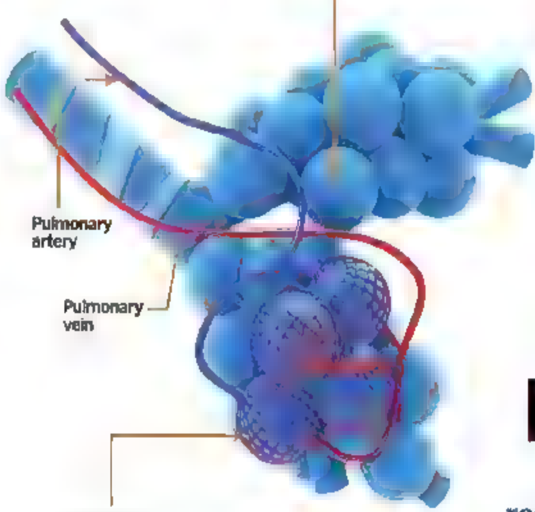
Respiration is crucial to an organism's survival. The process of respiration is the transportation of oxygen from the air that surrounds us into the tissue cells of our body so that energy can be broken down

The primary organs used for respiration in humans are the lungs. Humans have two lungs, with the left lung being divided into two lobes and the right into three. Lungs have between 300–500 million alveoli, which is actually where gas exchange occurs.

Respiration of oxygen breaks into four main stages: ventilation, pulmonary gas exchange, gas transportation and peripheral gas exchange. Each stage is crucial in getting oxygen to the body's tissue, and removing carbon dioxide. Ventilation and gas transportation need energy to occur, as the diaphragm and the heart are used to facilitate these actions, whereas gas exchanging is passive. As air is drawn into the lungs at a rate of between 10-20 breaths per minute while resting, through either your mouth or nose by diaphragm contraction, and travels through the pharynx, then the larynx, down the trachea, and into one of the two main bronchial tubes. Mucus and cilia keep the lungs clean by catching dirt particles and sweeping them up the trachea.

When air reaches the lungs, oxygen is diffused into the bloodstream through the alveoli and carbon dioxide is diffused from the blood into the lungs to be exhaled. Diffusion of gases occurs because of differing pressures in the lungs and blood. This is also the same when oxygen diffuses into tissue around the body. When blood has been oxygenated by the lungs, it is transferred around the body to where it is most needed in the bloodstream. If the body is exercising, the breathing rate increases and, consequently, so does the heart rate to ensure that oxygen reaches tissues that need it. Oxygen is then used to break down glucose to provide energy for the body. This happens in the mitochondria of cells. Carbon dioxide is one of the waste products of this, which is why we get a build up of this gas in our body that needs to be transported back into the lungs to then be exhaled.

The body can also respire anaerobically, but this produces far less energy and instead of producing CO_2 as a byproduct, lactic acid is produced. The body then takes time to break this down after exertion has finished as the body has a so-called oxygen debt.



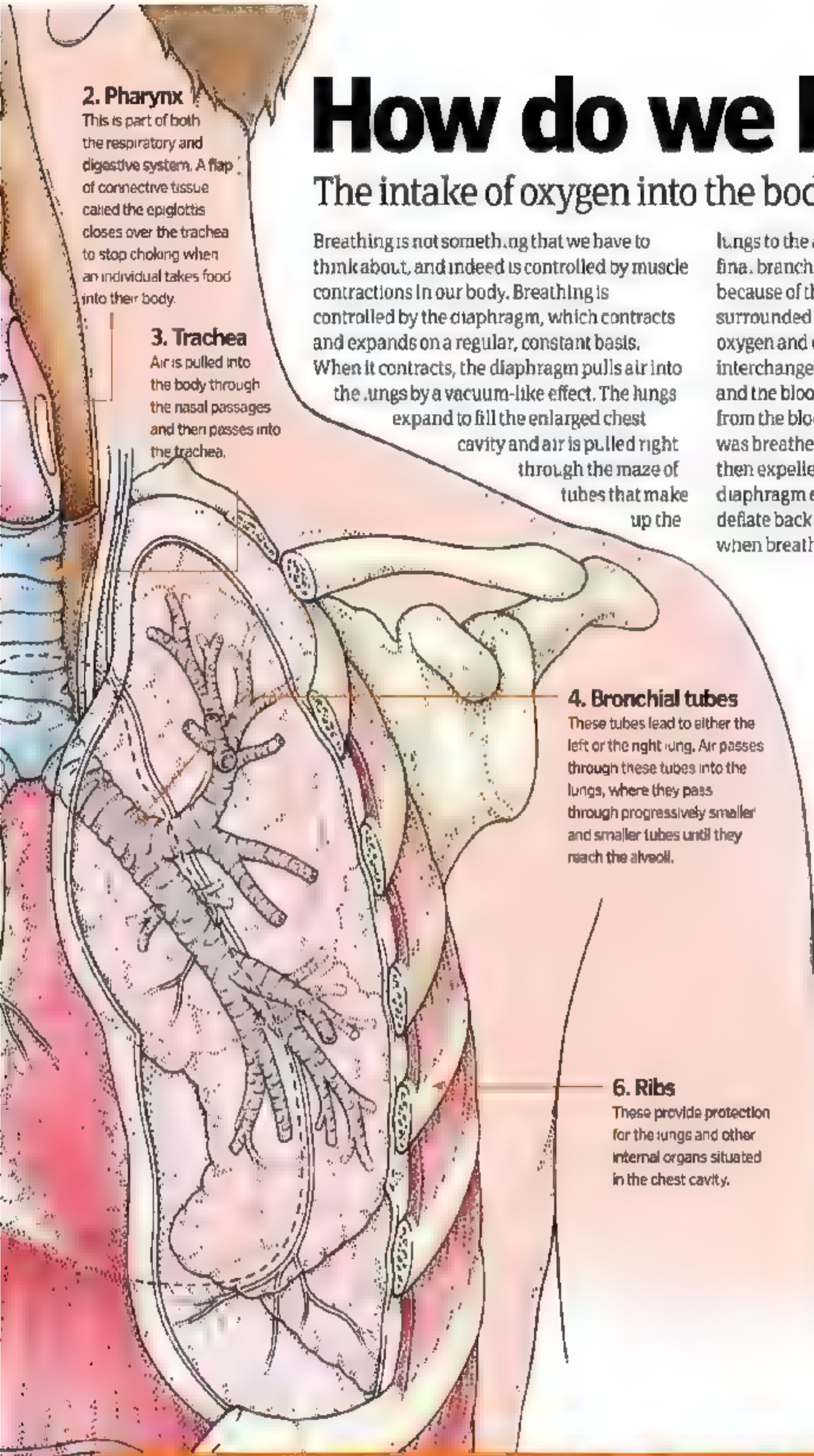
How our lungs work

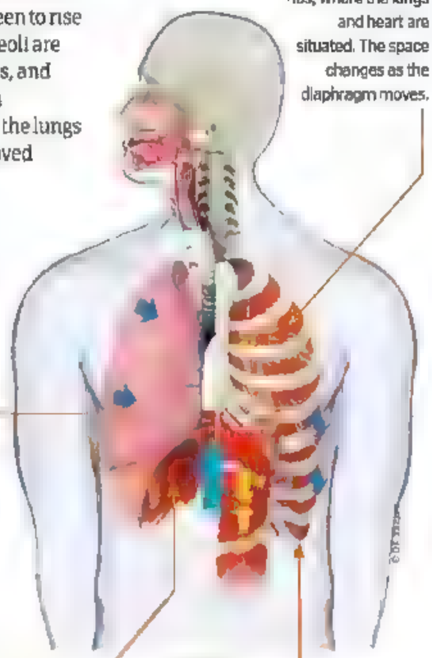
Lungs are the major respiratory organ in humans

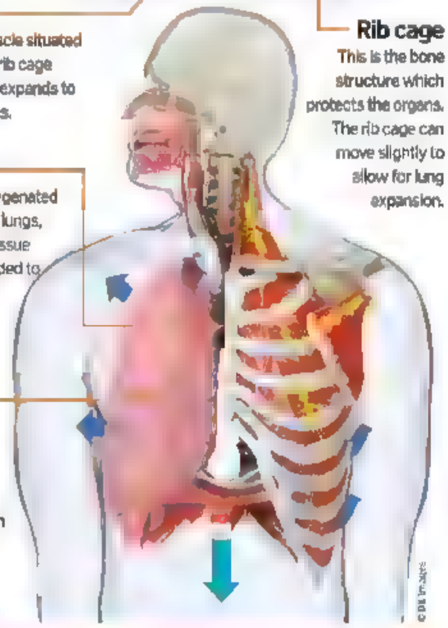
How do we breathe?

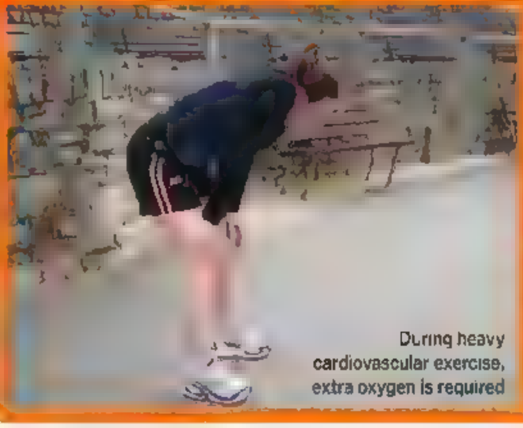
The intake of oxygen into the body is complex

Breathing is not something that we have to think about, and indeed is controlled by muscle contractions in our body. Breathing is controlled by the diaphragm, which contracts and expands on a regular, constant basis. When it contracts, the diaphragm pulls air into the lungs by a vacuum-like effect. The lungs expand to fill the enlarged chest cavity and air is pulled right through the maze of tubes that make up the lungs to the alveoli at the ends, which are the final branching. The chest will be seen to rise because of this lung expansion. Alveoli are surrounded by various blood vessels, and oxygen and carbon dioxide are then interchanged at this point between the lungs and the blood. Carbon dioxide removed from the blood stream and air that was breathed in but not used is then expelled from the lungs by diaphragm expansion. Lungs deflate back to a reduced size when breathing out.



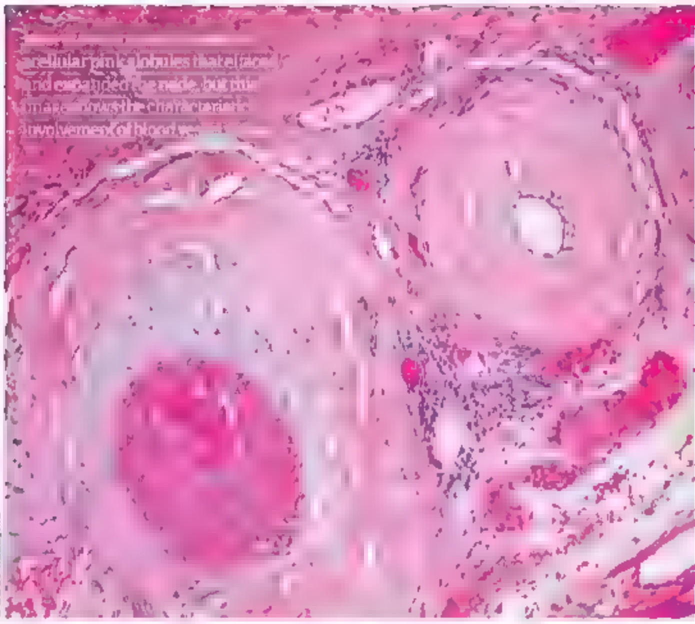





During heavy cardiovascular exercise, extra oxygen is required

Why do we need oxygen?

Inside the circulatory system



© Ed Uthman, MD

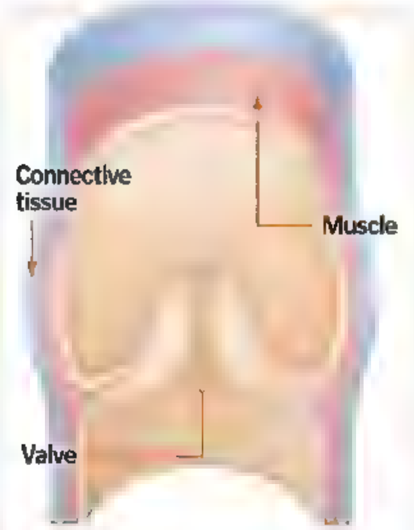
Arteries and veins form the plumbing system that carries blood around the body. Find out more about the circular journey it takes...

The network of blood vessels in the human body must cope with different volumes of blood travelling at different pressures. These blood vessels come in a multitude of different sizes and shapes, from the large, elastic aorta down to very tiny, one-cell-thick capillaries.

Blood is the ultimate multitasker. It carries oxygen for various tissues to use, nutrients to provide energy, removes waste products and even helps you warm up or cool down. It also carries vital clotting factors which stop us bleeding. Blood comes in just two varieties; oxygen-rich (oxygenated) blood is what the body uses for energy, and is bright red. After it has been used, this oxygen-depleted (deoxygenated) blood is returned for recycling and is actually dark red (not blue, as is often thought).

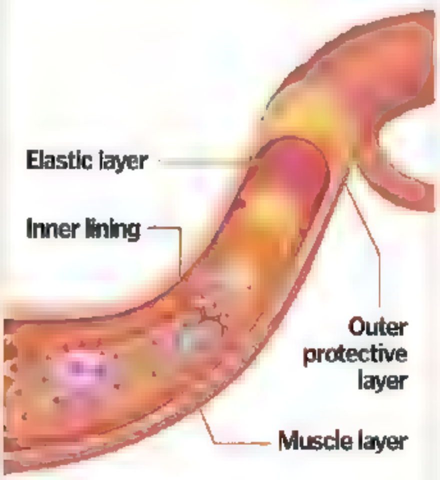
Blood is carried in vessels, of which there are two main different types – arteries and veins. Arteries carry blood away from the heart and deal with high pressures, and so have strong elastic walls. Veins carry blood back towards the heart and deal with lower pressures, so have thinner walls. Tiny capillaries connect arteries and veins together, like small back-roads connecting motorways to dual carriageways.

Arteries and veins are constructed differently to cope with the varying pressures, but work in tandem to ensure that the blood reaches its final destination. However, sometimes things go wrong, lead to certain medical problems: varicose veins from failing valves; deep vein thrombosis from blood clots blocking the deep venous system; heart attacks from blocked arteries; and lastly life-threatening aneurysms from weak artery walls.



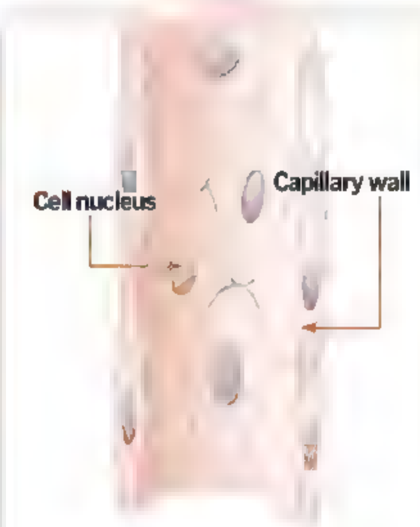
How do veins work?

Veins carry low pressure blood. They contain numerous one-way valves which stop backwards flow of blood, which can occur when pressure falls in-between heartbeats. Blood flows through these valves towards the heart but cannot pass back through them in the other direction. Valves can fail over time, especially in the legs. This leads to saggy, unsightly veins, known as varicose veins



Arteries – under pressure!

Arteries cope with a lot of the pressure generated by the heart and deliver oxygen-rich blood to where it needs to be 24 hours a day. The walls of arteries contain elastic muscles, which allow them to stretch and contract to cope with the wide changes in pressure which is generated from the heart. Since the pressure is high, valves are unnecessary, unlike the low-pressure venous system.

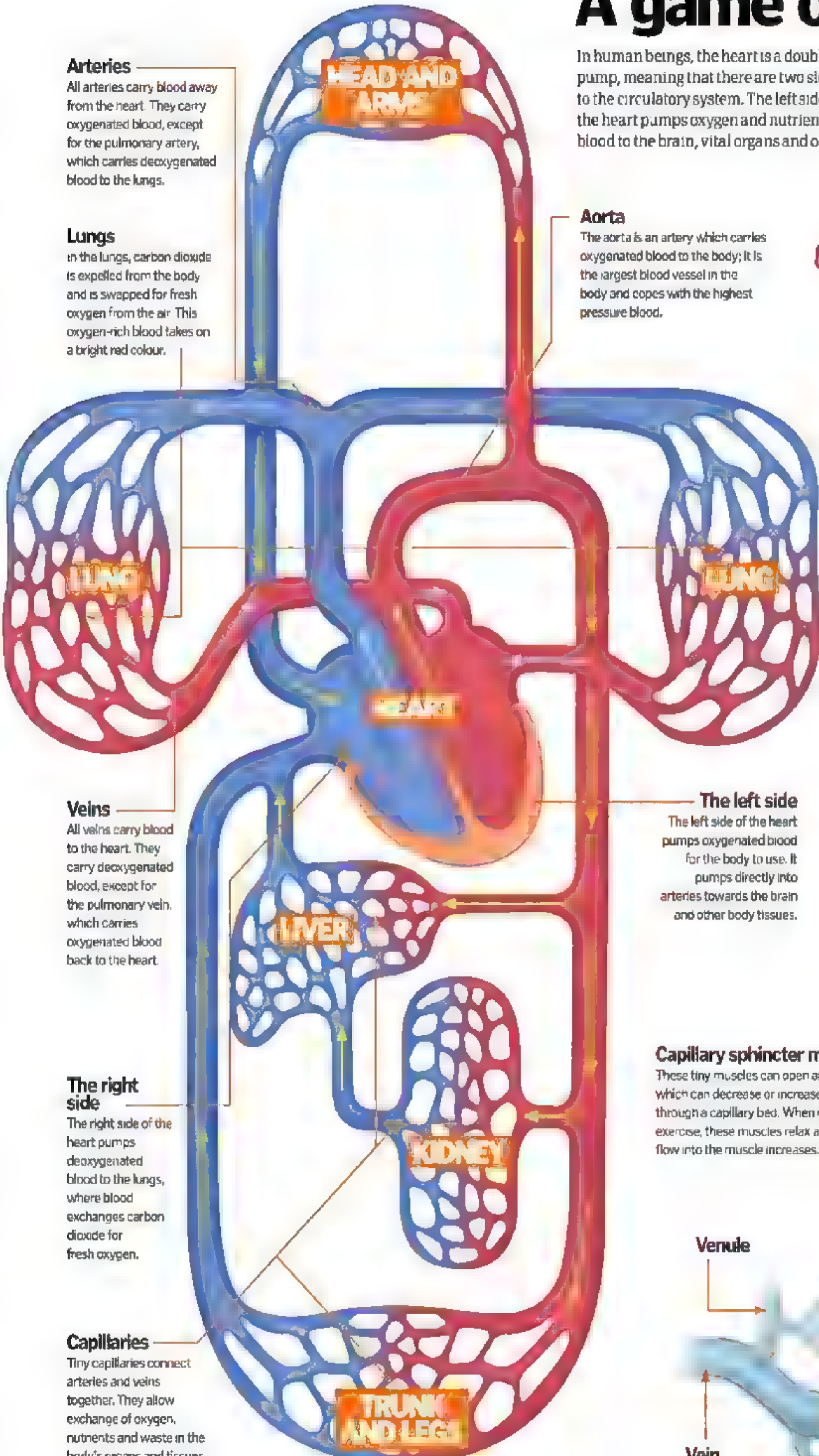


Connecting it all together

Capillaries are the tiny vessels which connect small arteries and veins together. Their walls are only one cell thick, so this is the perfect place to trade substances with surrounding tissues. Red blood cells within these capillaries trade water, oxygen, carbon dioxide, nutrients, waste and even heat. Because these vessels are only one cell wide, the cells have to line up to pass through.

A game of two halves

In human beings, the heart is a double pump, meaning that there are two sides to the circulatory system. The left side of the heart pumps oxygen and nutrient-rich blood to the brain, vital organs and other body tissues (the systemic circulation). The right side of the heart pumps deoxygenated blood towards the lungs, so it can pick up new oxygen molecules to be used again (the pulmonary circulation).



Arteries
All arteries carry blood away from the heart. They carry oxygenated blood, except for the pulmonary artery, which carries deoxygenated blood to the lungs.

Lungs
In the lungs, carbon dioxide is expelled from the body and is swapped for fresh oxygen from the air. This oxygen-rich blood takes on a bright red colour.

Veins
All veins carry blood to the heart. They carry deoxygenated blood, except for the pulmonary vein, which carries oxygenated blood back to the heart.

The right side
The right side of the heart pumps deoxygenated blood to the lungs, where blood exchanges carbon dioxide for fresh oxygen.

Capillaries
Tiny capillaries connect arteries and veins together. They allow exchange of oxygen, nutrients and waste in the body's organs and tissues.

Aorta
The aorta is an artery which carries oxygenated blood to the body; it is the largest blood vessel in the body and copes with the highest pressure blood.

The left side
The left side of the heart pumps oxygenated blood for the body to use. It pumps directly into arteries towards the brain and other body tissues.

"Plasma carries all of the different types of cells"

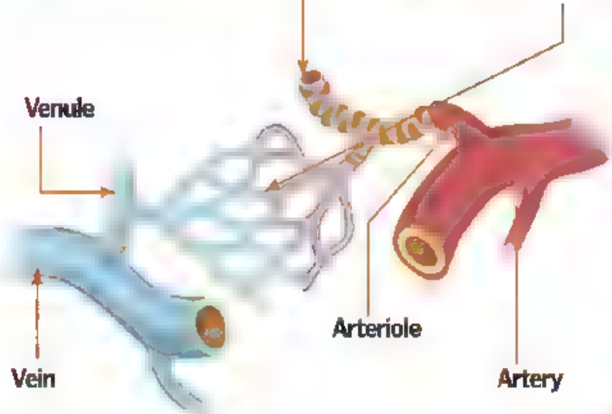
What's in blood?

Blood vessels

Different shapes and sizes

Capillary sphincter muscles
These tiny muscles can open and close, which can decrease or increase blood flow through a capillary bed. When muscles exercise, these muscles relax and blood flow into the muscle increases.

Capillary bed
This is the capillary network that connects the two systems. Here, exchange of various substances occurs with surrounding tissues, through the one-cell thick walls.



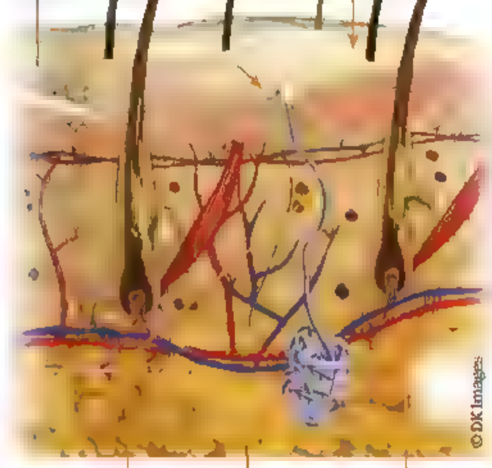
Why do we sweat?

As your doctor may tell you, it's glandular…

Sweat is produced by dedicated sweat glands, and is a mechanism used primarily by the body to reduce its internal temperature. There are two types of sweat gland in the human body, the eccrine gland and the apocrine gland. The former regulates body temperature, and is the primary source of excreted sweat, with the latter only secreting under emotional stresses, rather than those involved with body dehydration.

Eccrine sweat glands are controlled by the sympathetic nervous system and, when the internal temperature of the body rises, they secrete a salty, water-based substance to the skin's surface. This liquid then cools the skin and the body through evaporation, storing and then transferring excess heat into the atmosphere.

Both the eccrine and apocrine sweat glands only appear in mammals and, if they are active over the majority of the animal's body, they act as the primary thermoregulatory device. Certain mammals such as dogs, cats and sheep only have eccrine glands in specific areas – such as paws and lips – warranting the need for them to pant in order to control their temperature.



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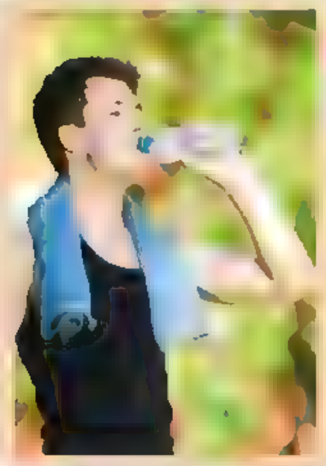
Dehydration

What happens if we don't drink enough?

Just by breathing, sweating and urinating, the average person loses ten cups of water a day. With H2O making up as much as 75 per cent of our body, dehydration is a frequent risk. Water is integral in maintaining our systems and it performs limitless functions.

Essentially, dehydration strikes when your body takes in less fluid than it loses. The mineral balance in your body becomes upset with salt and sugar levels going haywire. Enzymatic activity is slowed, toxins accumulate more easily and your breathing can even become more difficult as the lungs are having to work harder.

Babies and the elderly are most susceptible as their bodies are not as resilient as others. It has been recommended to have eight glasses of water or two litres a day. More recent research is undecided as to how much is exactly needed.

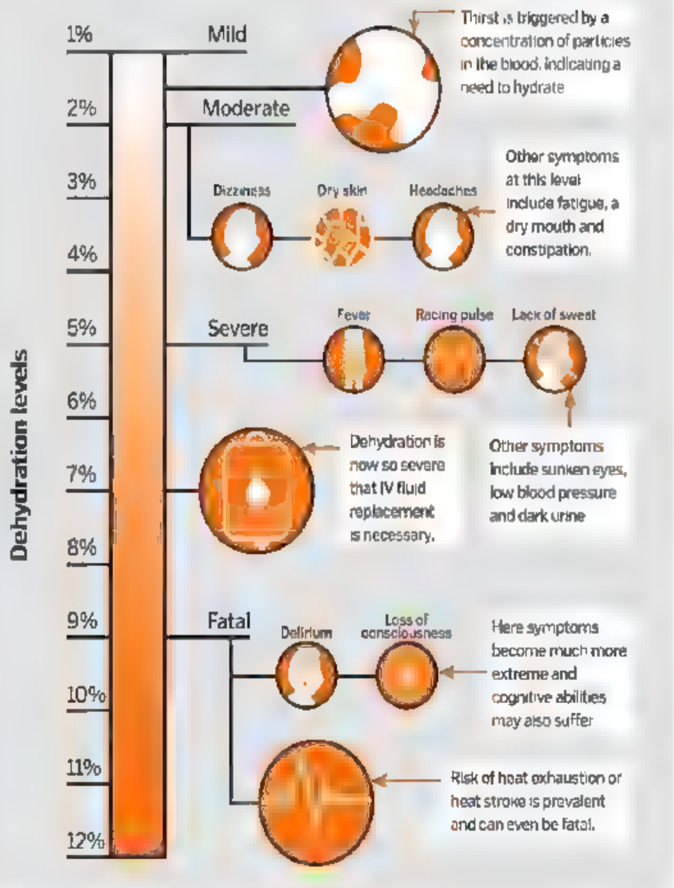


Too much H_2O?

Hydration is all about finding the perfect balance. Too much hydration is just as harmful as well as drinking too little; this is known as water intoxication. If an individual has too much liquid in their body, nutrients such as electrolytes and sodium are diluted and the body suffers. Your cells will begin to bloat and expand to such a point that they can even burst, and it can be fatal if untreated with IV fluids containing electrolytes.

Dangers of dehydration

How does a lack of water vary from mild to fatal?



How wounds heal

It takes an army of cells to repair cuts and scrapes

Wound healing happens in four key stages: haemostasis, inflammation, proliferation and remodelling. Haemostasis means 'blood halting' in Greek, and is the first crucial part in closing a wound. The body's first line of defence is to constrict the blood vessels in the affected area to minimise blood loss. Platelets then start to stick to the exposed tissue, becoming activated and encouraging more and more platelets to clump together to plug the gap.

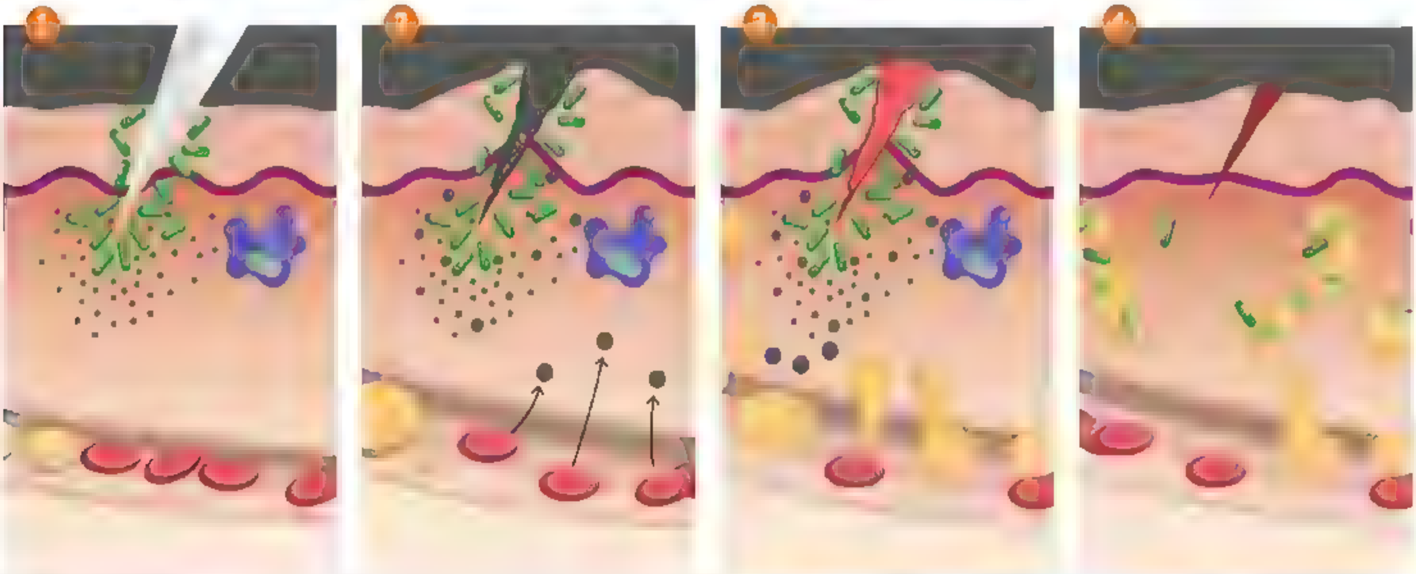
Once this plug is in place, a mesh of fibrin fibres starts to form around it, trapping passing blood cells and forming a sturdy clot that holds the wound closed until it can be repaired. This process only takes a matter of minutes, and once the bleeding stops, the local blood vessels dilate again, allowing immune cells to reach the area and begin the necessary repairs. This stage is called inflammation.

White blood cells go in and clear up dead cells, get rid of damaged tissue and chase down any pathogens that have entered through the wound and destroy them by phagocytosis (ingesting them). They also prepare the area for the repair phase, which is known as proliferation.

With the encouragement of the immune system, long, spindle-shaped cells called fibroblasts start rebuilding the collagen scaffolding that holds healthy tissue together. On top of the wound, epithelial cells begin dividing and migrating to cover the gap. New blood vessels start to form and, as the tissue heals, myofibroblasts tug at the edges of the wound to close the hole. Once this stage is complete, it's time for remodelling. The scaffolding built by the fibroblasts is rearranged, and any unneeded cells that were made during the healing process are safely removed.

Halting infection

The immune system rushes in to prevent pathogens entering through an open wound



© SPL; Illustration by Ed Crooks

How your blood works

The science behind the miraculous fluid that feeds, heals and fights for your life

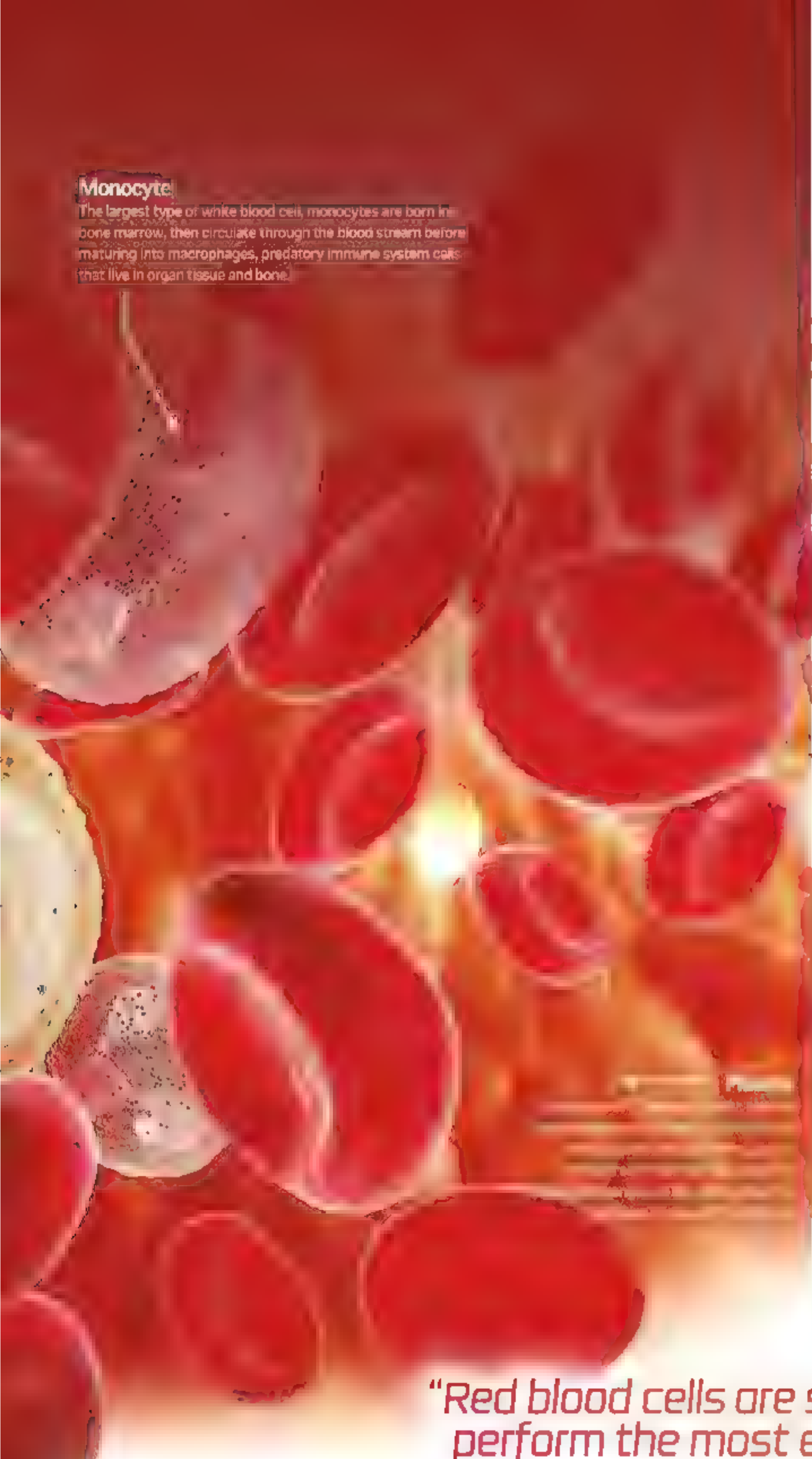
White blood cells
White blood cells, or leukocytes, are the immune system's best weapon, searching out and destroying bacteria and producing antibodies against viruses. There are five different types of white blood cells, all with distinct functions.

Platelet
When activated, these sticky cell fragments are essential to the clotting process. Platelets adhere to a wound opening to stem the flow of blood, then they team with a protein called fibrinogen to weave tiny threads that trap blood cells.

Red blood cell
Known as erythrocytes, red blood cells are the body's delivery service, shuttling oxygen from the lungs to living cells throughout the body and returning carbon dioxide as waste.

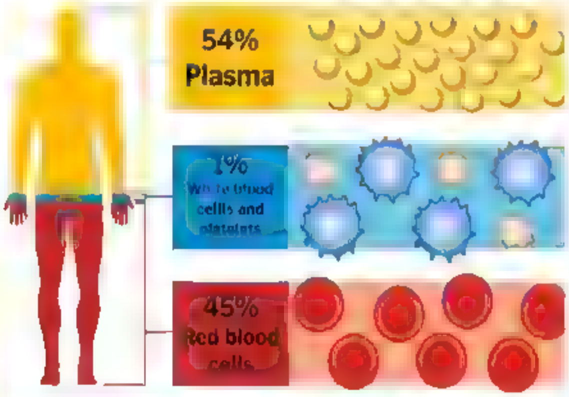
Blood vessel wall
Arteries and veins are composed of three tissue layers, a combination of elastic tissue, connective tissue and smooth muscle fibres that contract under signals from the sympathetic nervous system.

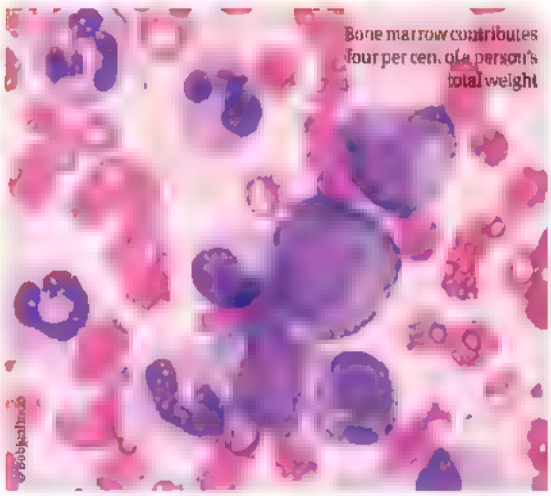
Granulocyte
The most numerous type of white blood cell, granulocytes patrol the bloodstream destroying invading bacteria by engulfing and digesting them, often dying in the process.



Components of blood

Blood is a mix of solids and liquids, a blend of highly specialised cells and particles suspended in a protein-rich fluid called plasma. Red blood cells dominate the mix, carrying oxygen to living tissue and returning carbon dioxide to the lungs. For every 600 red blood cells, there is a single white blood cell, of which there are five different kinds. Cell fragments called platelets use their irregular surface to cling to vessel walls and initiate the clotting process.





Bone marrow contributes four per cent of a person's total weight

> "Red blood cells are so numerous because they perform the most essential function of blood"

Blood is the river of life. It feeds oxygen and essential nutrients to living cells and carries away waste. It transports the foot soldiers of the immune system, white blood cells, which seek out and destroy invading bacteria and parasites. And it then speeds platelets to the site of injury or tissue damage, triggering the body's miraculous process of self-repair.

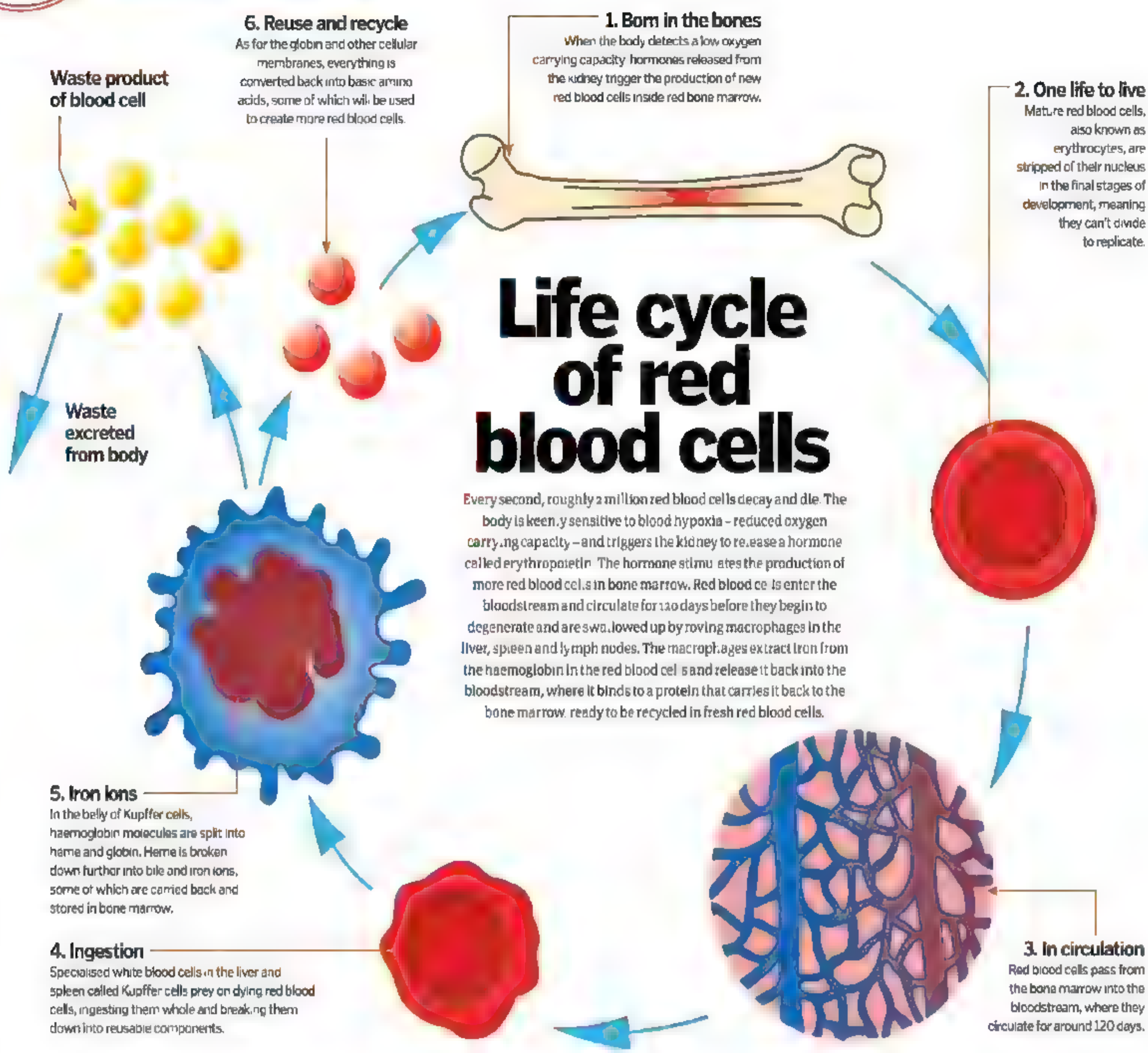
Blood looks like a thick, homogenous fluid, but it's actually more like a watery current of plasma – a straw-coloured, protein-rich fluid – carrying billions of microscopic solids consisting of red blood cells, white blood cells and cell fragments that are called platelets. The distribution is far from equal. Over half of our blood is actually just plasma, 45 per cent is red blood cells and a tiny fragment, less than one per cent, is composed of white blood cells and platelets.

Red blood cells are so numerous because they perform the most essential function of blood, which is to deliver oxygen to every cell in the body and carry away carbon dioxide. As an adult, all of your red blood cells are produced in red bone marrow, the spongy tissue in the bulbous ends of long bones and at the centre of flat bones like hips and ribs.

In the marrow, red blood cells start out as undifferentiated stem cells called hemocytoblasts. If the body detects a drop in oxygen carrying capacity, a hormone is released from the kidneys that triggers the stem cells to become red blood cells. Because red blood cells only live 120 days, the supply is continuously replenished; roughly 2 million red blood cells every second. A mature red blood cell has no nucleus, it is spit out during the final stages of the two-day development before taking on the shape of a concave, doughnut-like disc. Red blood cells are mostly water, but 97 per cent of their solid matter is haemoglobin, a complex protein that carries four atoms of iron. Those iron atoms have the ability to form loose, reversible bonds with both oxygen and carbon dioxide – think of them as weak magnets – making red blood cells such an effective transport system for all of the respiratory gasses. Haemoglobin, which turns bright red

Life cycle of red blood cells

Every second, roughly 2 million red blood cells decay and die. The body is keenly sensitive to blood hypoxia – reduced oxygen carrying capacity – and triggers the kidney to release a hormone called erythropoietin. The hormone stimulates the production of more red blood cells in bone marrow. Red blood cells enter the bloodstream and circulate for 120 days before they begin to degenerate and are swallowed up by roving macrophages in the liver, spleen and lymph nodes. The macrophages extract iron from the haemoglobin in the red blood cells and release it back into the bloodstream, where it binds to a protein that carries it back to the bone marrow, ready to be recycled in fresh red blood cells.



when oxygenated, is what gives blood its characteristic crimson colour.

To provide oxygen to every living cell, red blood cells must be pumped through the body's circulatory system. The right side of the heart pumps CO_2-heavy blood into the lungs, where it releases its waste gasses and picks up oxygen. The left side of the heart then automatically pumps all of the freshly oxygenated blood out into the body through a system of various arteries and capillaries, some are even as narrow as a single cell. As the red blood cells release their oxygen, they pick up carbon dioxide molecules, then they course through the veins back toward the heart, where they are pumped back into the lungs to 'exhale' the excess CO_2 and collect some more precious O_2. White blood cells are actually greatly outnumbered by red blood cells, but they are critical to the function of the immune system. Most white blood cells are also produced in red bone marrow, but white blood cells – unlike red blood cells – come in five different varieties, each with its own specialised immune function. The first three varieties of blood cells, are called granulocytes, engulf and digest bacteria and parasites, and play a role in allergic reactions. Lymphocytes, another type of white blood cell, produce anti-bodies that build up our immunity to repeat intruders. And monocytes, the largest of the white blood cells, enter organ tissue and become macrophages, microbes that ingest bad bacteria and then help break down dead red blood cells into reusable parts.

Platelets aren't cells at all, they are actually tiny fragments from much larger stem cells found in bone marrow. In their resting state, they look like smooth oval plates, but when activated to form a clot they take on an irregular form with many protruding arms called pseudopods. This shape is what helps them to be able to stick not only to the blood vessel walls but also to each other, forming a physical barrier around wound sites. With the help of proteins and clotting factors that are found inside plasma, platelets weave a mesh of fibrin that stems blood loss and triggers the formation of new collagen and skin cells. But three functions of blood – oxygen supplier, immune system defender and wound healer – only scratch the surface of the critical role of blood in each and every bodily process. When blood circulates through the small intestine, it absorbs sugars from digested food, which are transported to the liver to be stored as energy. When blood passes through the kidneys, it is scrubbed of excess urea and salts, waste that will leave the body as urine. The proteins transport vitamins, hormones, enzymes, sugar and electrolytes.

Blood disorders

Blood is a delicate balancing act, with the body constantly regulating oxygen flow, iron content and clotting ability. Unfortunately, there are several genetic conditions and chronic illnesses that can disturb the balance, sometimes with deadly consequences

"Platelets weave a mesh of fibrin that stems blood loss"

Haemophilia

This rare genetic blood disorder severely inhibits the clotting mechanism of blood, causing excessive bleeding, internal bruising and joint problems. Platelets are essential to the clotting and healing process, producing threads of fibrin with help from proteins in the bloodstream called clotting factors. People who suffer from haemophilia – almost exclusively males – are missing one of those clotting factors, making it difficult to seal off blood vessels after even minor injuries.

Sickle cell anaemia

Anaemia is the name for any blood disorder that results in a dangerously low red blood cell count. In sickle cell anaemia, which afflicts one out of every 625 children of African descent, red blood cells elongate into a sickle shape after releasing their oxygen. The sickle-shaped cells die prematurely, leading to anaemia, or sometimes lodge in blood vessels, causing terrible pain and even organ damage. Interestingly, people who carry only one gene for sickle cell anaemia are immune to malaria.

Left to right: a red blood cell, platelet and white blood cell

Thalassemia

Another rare blood disorder affecting 100,000 newborns worldwide each year, thalassemia inhibits the production of haemoglobin, leading to severe anaemia. People who are born with the most serious form of the disease, also called Cooley's anaemia, suffer from enlarged hearts, livers and spleens, and brittle bones. The most effective treatment is frequent blood transfusions, although a few lucky patients have been cured through bone marrow transplants from perfectly matching donors.

Hemochromatosis

One of the most common genetic blood disorders, hemochromatosis is the medical term for "iron overload," in which your body absorbs and stores too much iron from food. Severity varies wildly, and many people experience few symptoms, but others suffer serious liver damage or scarring (cirrhosis), irregular heartbeat, diabetes and even heart failure. Symptoms can be aggravated by taking too much vitamin C.

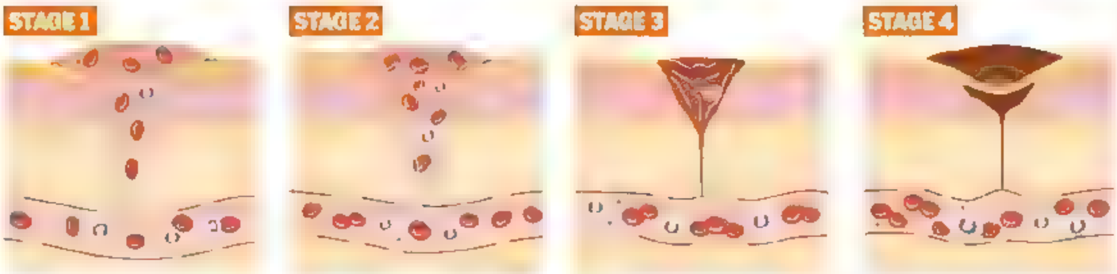
Deep vein thrombosis

Thrombosis is the medical term for any blood clot that is large enough to block a blood vessel. When a blood clot forms in the large, deep veins of the upper thigh, it's called deep vein thrombosis. If such a clot breaks free, it can circulate through the bloodstream, pass through the heart and become lodged in arteries in the lung, causing a pulmonary embolism. Such a blockage can severely damage portions of the lungs, and multiple embolisms can even be fatal.

Blood and healing

More than a one-trick pony, your blood is a vital cog in the healing process

Think of blood as the body's emergency response team to an injury. Platelets emit signals that encourage blood vessels to contract, stemming blood loss. The platelets then collect around the wound, reacting with a protein in plasma to form fibrin, a tissue that weaves into a mesh. Blood flow returns and white blood cells begin their hunt for bacteria. Fibroblasts create beds of fresh collagen and capillaries to fuel skin cell growth. The scab begins to contract, pulling the growing skin cells closer together until damaged tissue is replaced.



INJURY
When the skin surface is cut, torn or scraped deeply enough, blood seeps from broken blood vessels to fill the wound. To stem the flow of bleeding the blood vessels around the wound begin to constrict.

HAEMOSTASIS
Activated platelets aggregate around the surface of the wound, stimulating vasoconstriction. Platelets react with a protein in plasma to form fibrin, a web-like mesh of stringy tissue.

INFLAMMATORY STAGE
Once the wound is capped with a drying clot, blood vessels open up again, releasing plasma and white blood cells into the damaged tissue. Macrophages digest harmful bacteria and dead cells.

PROLIFERATIVE STAGE
Fibroblasts lay fresh layers of collagen inside the wound and capillaries begin to supply blood for the forming of new skin cells. Fibrin strands and collagen pull the sides of the wound together.

How do white blood cells work?

One of the body's main defences against infection and foreign pathogens, how do these cells protect our bodies?

White blood cells, or leukocytes, are the body's primary form of defence against disease. When the body is invaded by a pathogen of any kind, the white blood cells attack in a variety of ways; some produce antibodies, while others surround and ultimately devour the pathogens whole.

In total, there are five types of white blood cell (WBC), and each cell works in a different way to fight a variety of threats. These five cells sit in two groupings: the granulocytes and the agranulocytes. The groups are determined based on whether a cell has 'granules' in the cytoplasm. These granules are digestive enzymes that help break down pathogens. Neutrophils, eosinophils and basophils are all granulocytes, the enzymes in which also give them a distinct colouration which the agranulocytes do not have.

As the most common WBC, neutrophils make up between 55 and 70 per cent of the white blood cells in a normal healthy individual, with the other four types (eosinophils, basophils, monocytes and lymphocytes) making up the rest. Neutrophils are the primary responders to infection, actively moving to the site of infection following a call from mast cells after a pathogen is initially discovered. They consume bacteria and fungus that has broken through the body's barriers in a process called phagocytosis.

Lymphocytes – the second-most common kind of leukocyte – possess three types of defence cells: B cells, T cells and natural killer cells. B cells release antibodies and activate T cells, while T cells attack diseases such as viruses and tumours when directed, and regulatory T cells ensure the immune system returns to normal after an attack. Natural killer cells, meanwhile, aid T cell response by also attacking virus-infected and tumour cells, which lack a marker known as MHC.

The remaining types of leukocyte release chemicals such as histamine, preparing the body for future infection, as well as attacking other causes of illness like parasites.

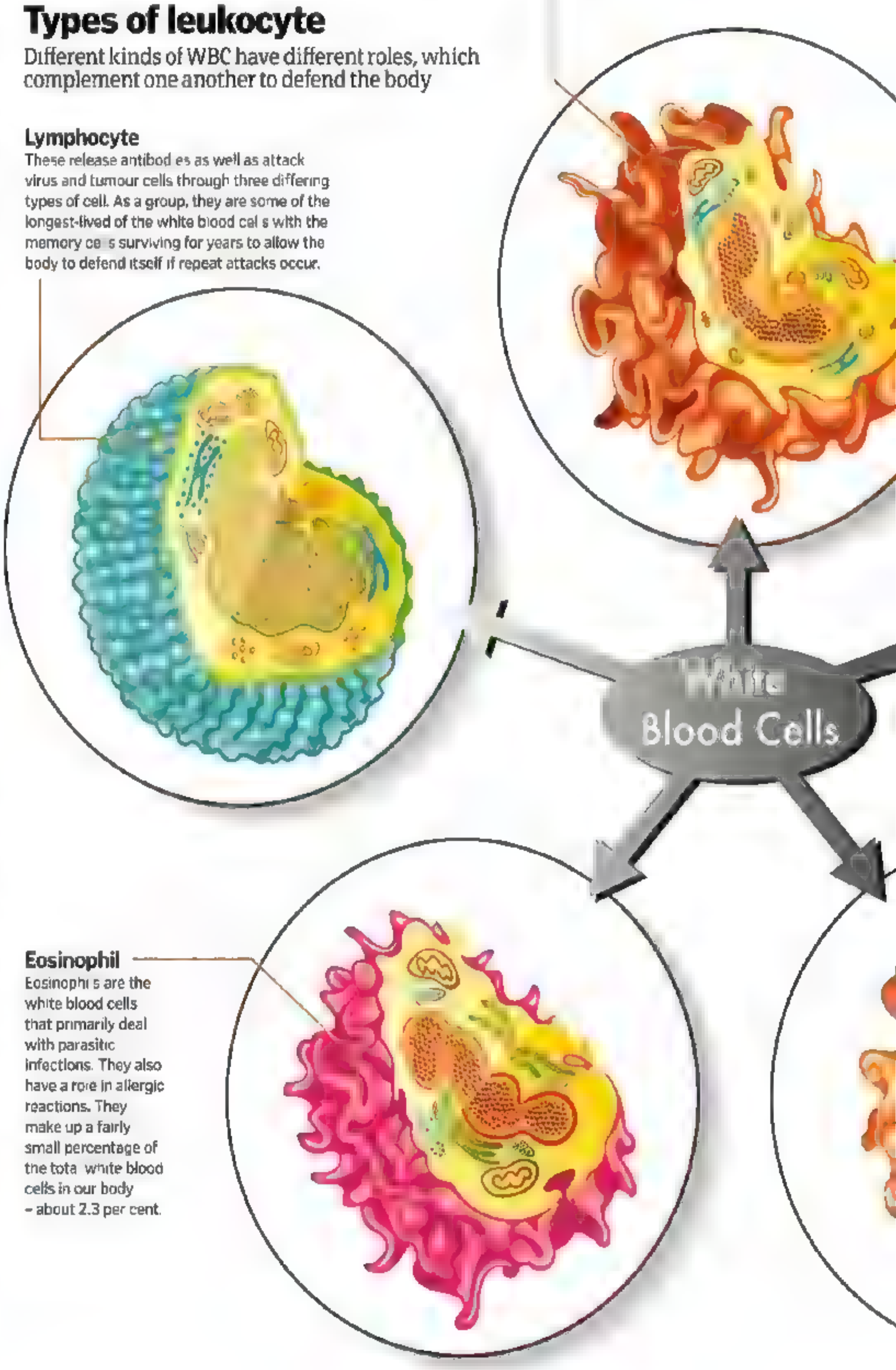
"Natural killer cells aid T cell response by also attacking virus-infected and tumour cells"

Types of leukocyte

Different kinds of WBC have different roles, which complement one another to defend the body

Monocyte
Monocytes help prepare us for another infection by presenting pathogens to the body so that antibodies can be created. Later in their life, monocytes move from the bloodstream into tissue, and then evolve into macrophages which can conduct phagocytosis.

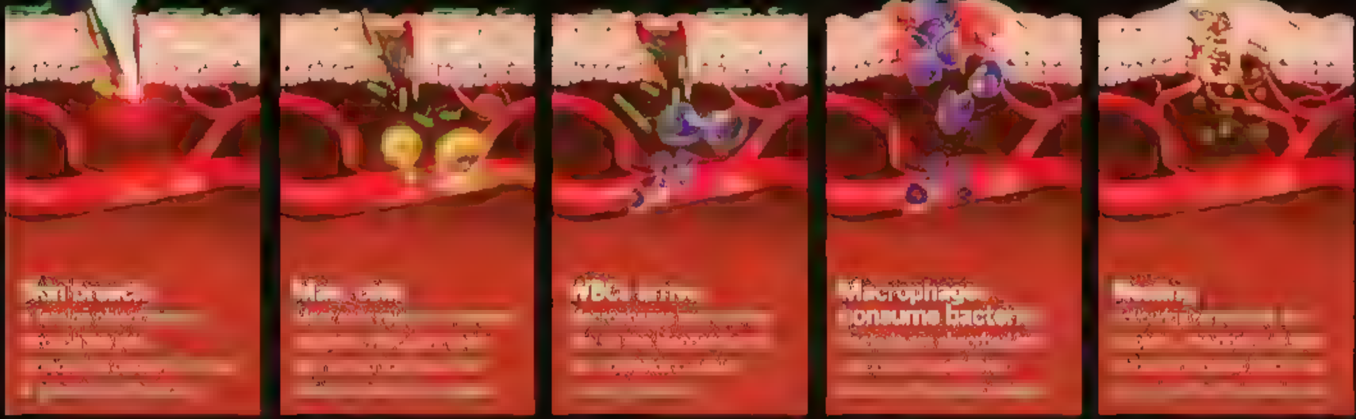
Lymphocyte
These release antibodies as well as attack virus and tumour cells through three differing types of cell. As a group, they are some of the longest-lived of the white blood cells with the memory cells surviving for years to allow the body to defend itself if repeat attacks occur.

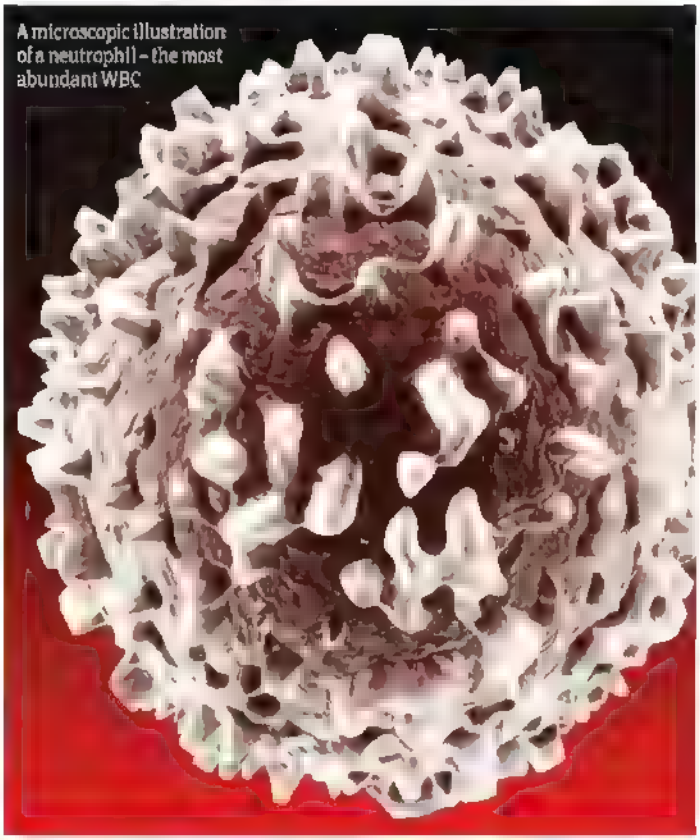


Eosinophil
Eosinophils are the white blood cells that primarily deal with parasitic infections. They also have a role in allergic reactions. They make up a fairly small percentage of the total white blood cells in our body – about 2.3 per cent.

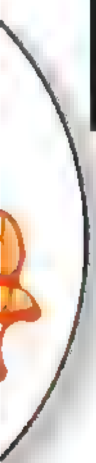
White blood cells at work

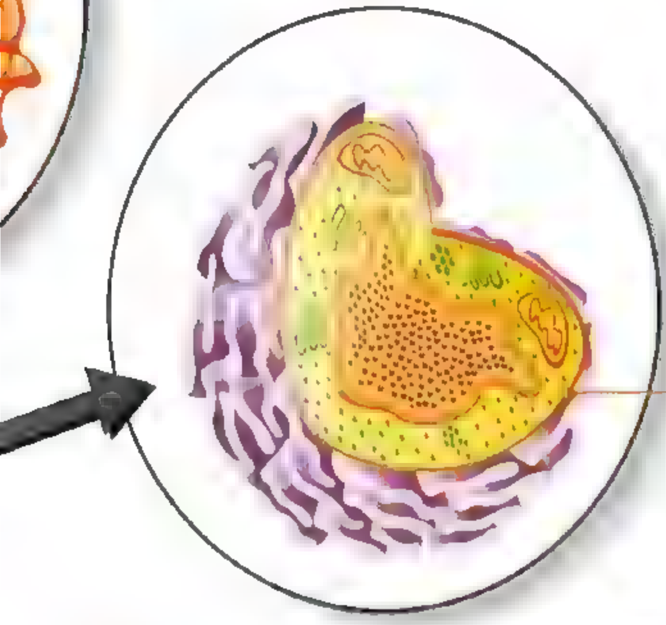
The body has various outer defences against infection, including the external barrier of the skin, but what happens when this is breached?



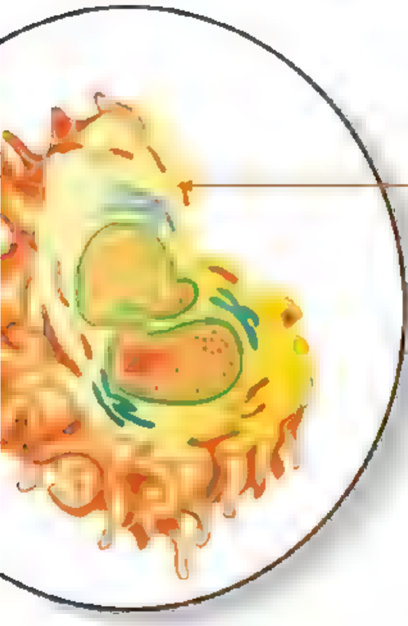


A microscopic illustration of a neutrophil – the most abundant WBC





Basophil
Basophils are involved in allergic response via releasing histamine and heparin into the bloodstream. Their functions are not fully known and they only account for 0.4 per cent of the body's white blood cells. Their granules appear blue when viewed under a microscope.



Neutrophil
Neutrophils are the most common of the leukocytes. They have a short lifespan so need to be constantly produced by the bone marrow. Their granules appear pink and the cell has multi-lobed nuclei which make them easily differentiated from other types of white blood cells.

A faulty immune system

How your immune system works

Physical defences

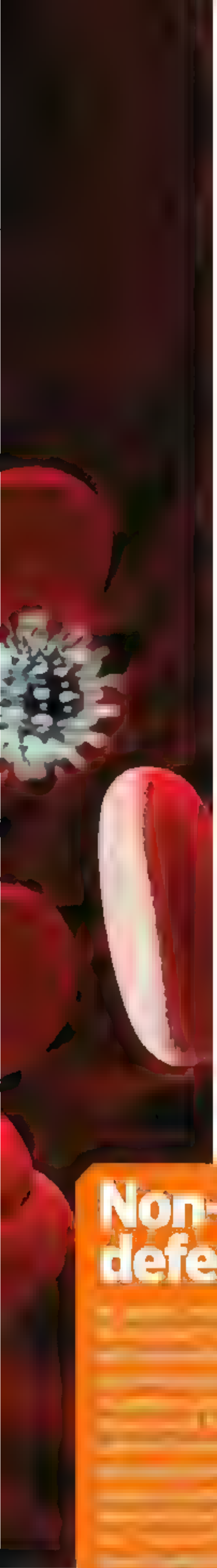
Human anatomy subscribes to the notion that good fences make good neighbours. Your skin, made up of tightly packed cells and an antibacterial oil coating, keeps most pathogens from ever setting foot in body. Your body's openings are well-fortified too. Pathogens that you inhale face a wall of mucus-covered membranes in your respiratory tract, optimised to trap germs. Pathogens that you digest end up soaking in a bath of potent stomach acid. Tears flush pathogens out of your eyes, dousing bacteria with a harsh enzyme for good measure.

Your body is locked in a constant war against a vicious army

It's true: while you're simply sitting around watching TV, trillions and trillions of foreign invaders are launching a full scale assault on the trillions of cells that constitute 'you'. Collectively known as pathogens, these attackers include bacteria, single-celled creatures that live to eat and reproduce; protists, larger single-cell organisms; viruses, packets of genetic information that take over host cells and replicate inside them; and fungi, a type of plant life.

Bacteria and viruses are by far the very worst offenders. Dangerous bacteria release toxins in the body that cause diseases such as E. coli, anthrax, and the black plague. The cell damage from viruses causes measles, the flu and the common cold, among numerous other diseases.

Just about everything in our environment is teeming with these microscopic intruders, including you. The bacteria in your stomach alone outnumber all the cells in your body, ten-to-one. Yet, your microscopic soldiers usually win against pathogens, through a combination of sturdy barriers, brute force, and superior battlefield intelligence, collectively dubbed the immune system.



The adaptive immune system

Fighting the good fight, and white blood cells are right on the front line...

When a pathogen is tough, wily, or numerous enough to survive various non-specific defences, it's down to the incredibly adaptive immune system to clean up the mess. The key forces in the adaptive immune system are white blood cells which are called lymphocytes. Unlike their macrophage cousins, these lymphocytes are engineered to attack only one specific type of pathogen. There are two types of lymphocytes: B-cells and T-cells.

These cells join the action when macrophages pass along information about the invading pathogen, through chemical messages called interleukins. After engulfing a pathogen, a macrophage communicates details about the pathogen's antigens – telltale molecules that actually characterise particular pathogens. Based on this information, the immune system identifies specific B-cells and T-cells equipped to recognise and battle the pathogen. Once they are successfully identified, these cells rapidly reproduce, assembling an army of cells that are equipped to take down the attacker.

The B-cells flood your body with antibodies, molecules that either disarm a specific pathogen or bind to it, marking it as a target for other white blood cells. When T-cells find their target, they lock on and release toxic chemicals that will destroy it. T-cells are especially adept at destroying your body's cells that are infected with a dangerous virus.

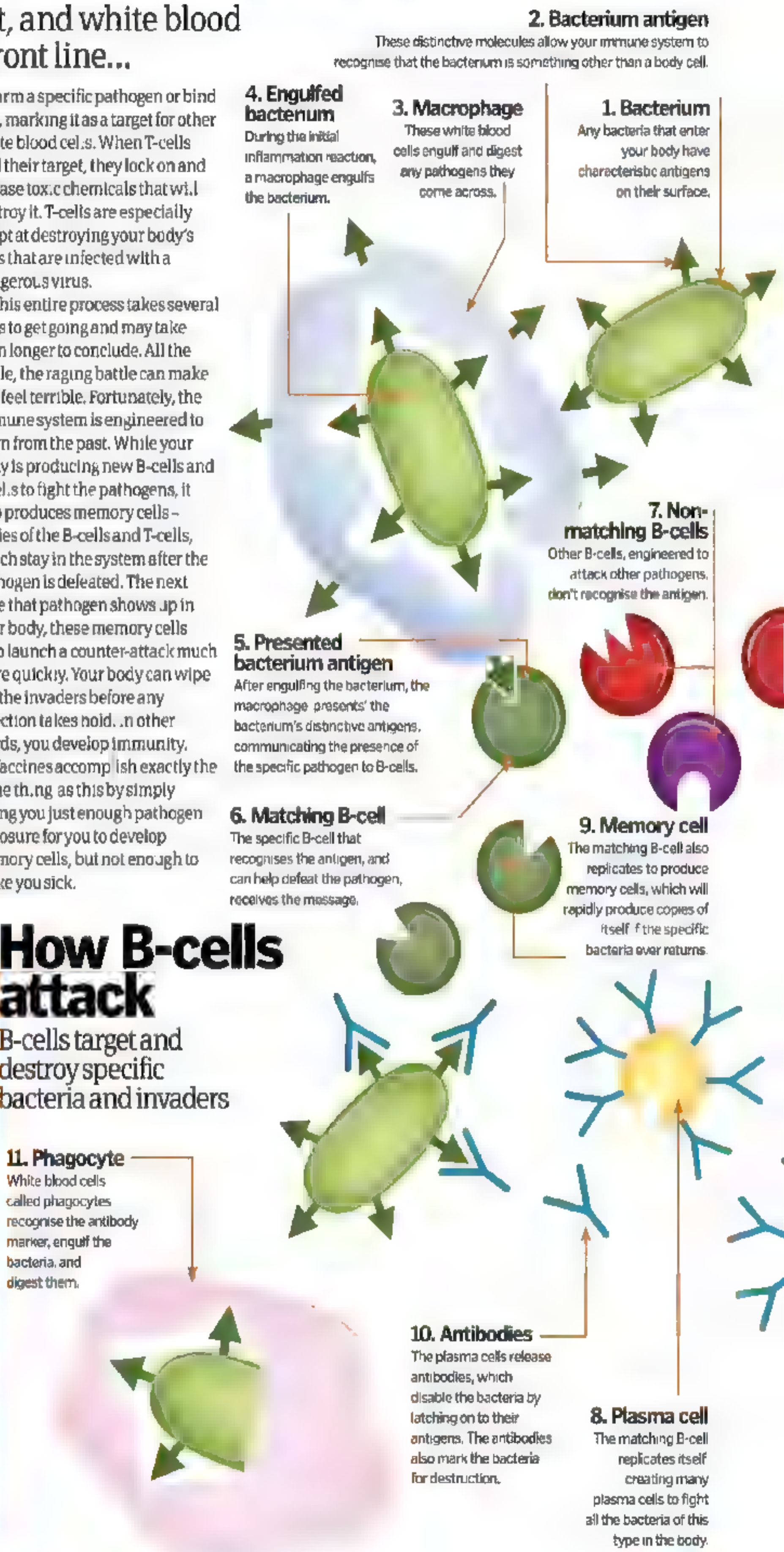
This entire process takes several days to get going and may take even longer to conclude. All the while, the raging battle can make you feel terrible. Fortunately, the immune system is engineered to learn from the past. While your body is producing new B-cells and T-cells to fight the pathogens, it also produces memory cells – copies of the B-cells and T-cells, which stay in the system after the pathogen is defeated. The next time that pathogen shows up in your body, these memory cells help launch a counter-attack much more quickly. Your body can wipe out the invaders before any infection takes hold. In other words, you develop immunity.

Vaccines accomplish exactly the same thing as this by simply giving you just enough pathogen exposure for you to develop memory cells, but not enough to make you sick.

Non-specific defences

How B-cells attack

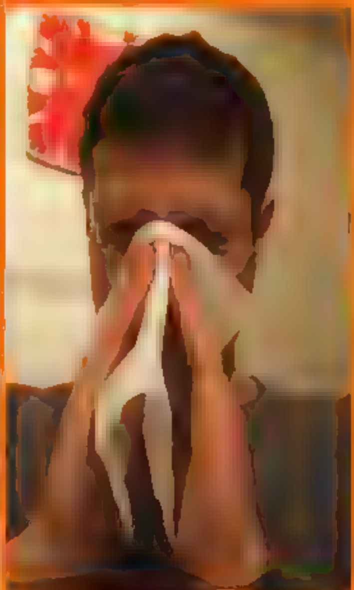
B-cells target and destroy specific bacteria and invaders



Your tonsils can help fight bacteria

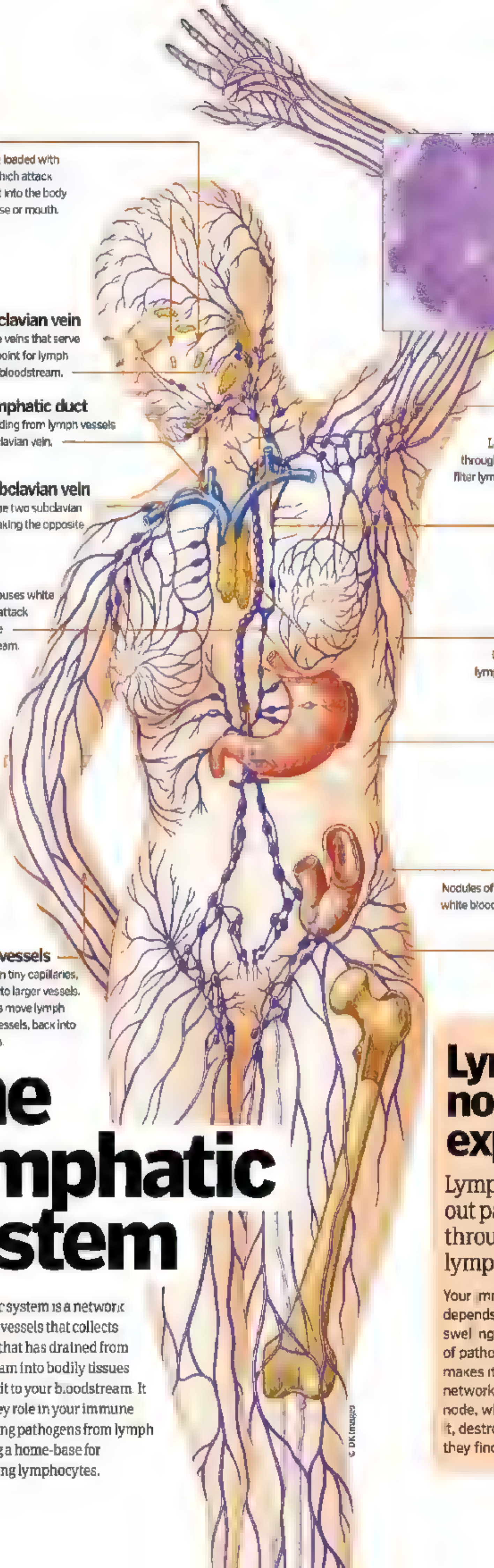
Disorders of the immune system

defences, so when it malfunctions



The lymphatic system

The lymphatic system is a network of organs and vessels that collects lymph – fluid that has drained from the bloodstream into bodily tissues – and returns it to your bloodstream. It also plays a key role in your immune system, filtering pathogens from lymph and providing a home-base for disease-fighting lymphocytes.



1. Tonsils
Lymphoid tissue loaded with lymphocytes, which attack bacteria that get into the body through your nose or mouth.

2. Left subclavian vein
One of two large veins that serve as the re-entry point for lymph returning to the bloodstream.

3. Right lymphatic duct
Passageway leading from lymph vessels to the right subclavian vein.

4. Right subclavian vein
The second of the two subclavian veins, this one taking the opposite path to its twin.

5. Spleen
An organ that houses white blood cells that attack pathogens in the body's bloodstream.

6. Lymph node cluster
Located along lymph vessels throughout the body, lymph nodes filter lymph as it makes its way back into the bloodstream.

7. Left lymphatic duct
Passageway leading from lymph vessels to the left subclavian vein.

8. Thymus gland
Organ that provides area for lymphocytes produced by bone marrow to mature into specialised T-cells.

9. Thoracic duct
The largest lymph vessel in the body.

10. Lymph vessels
Lymph collects in tiny capillaries, which expand into larger vessels. Skeletal muscles move lymph through these vessels, back into the bloodstream.

11. Peyer's patch
Nodules of lymphoid tissue supporting white blood cells that battle pathogens in the intestinal tract.

12. Bone marrow
The site of all white blood cell production.

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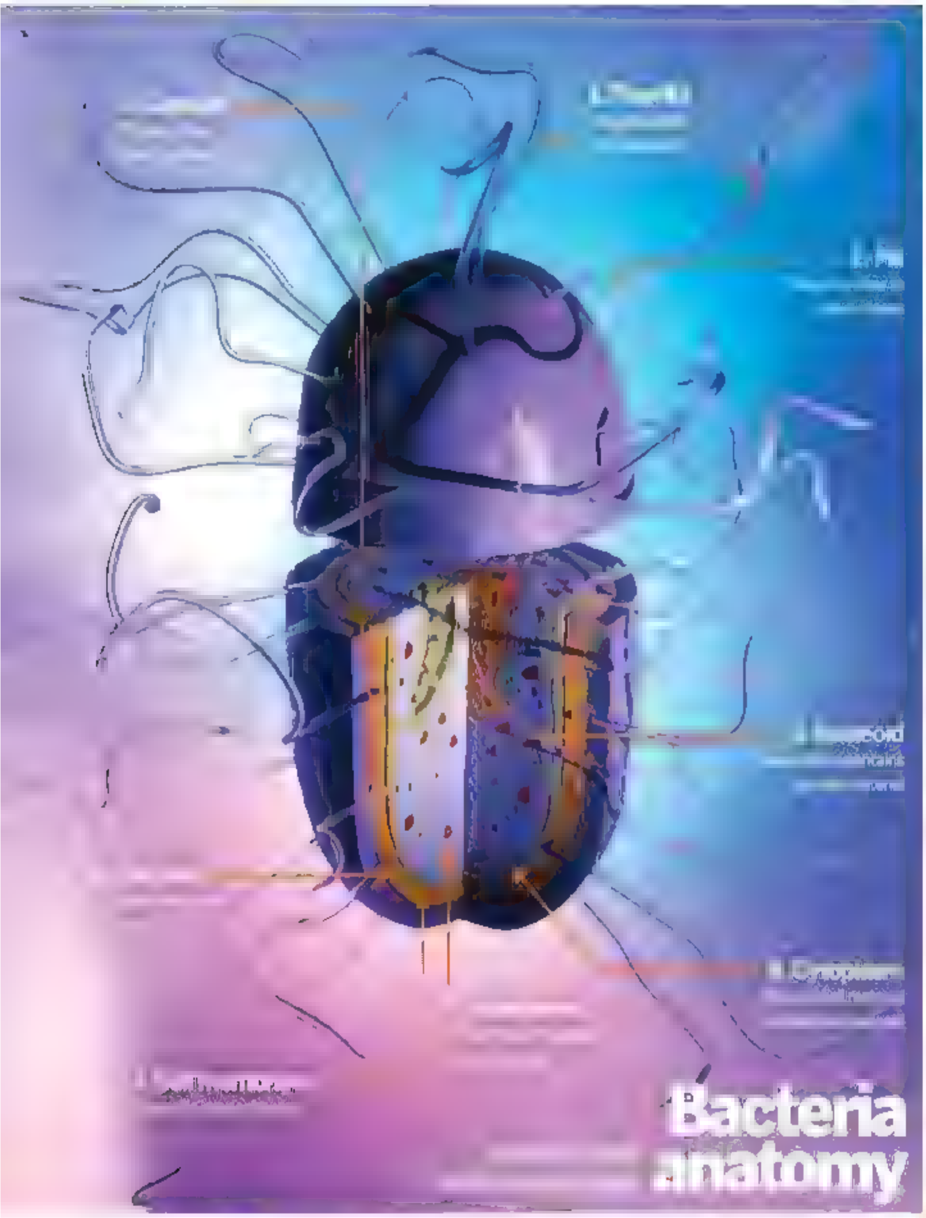
Lymph nodes explained

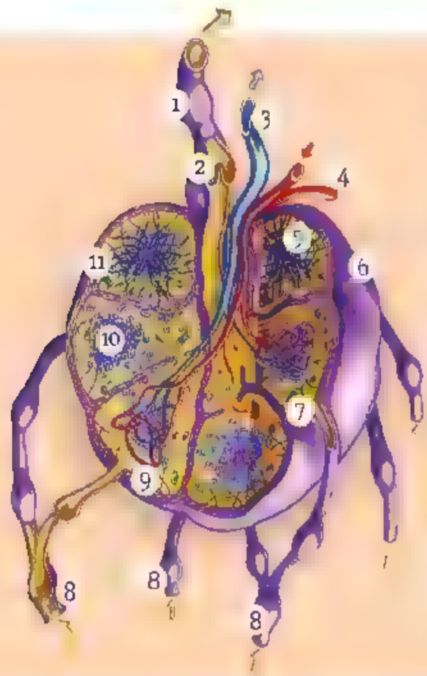
Lymph nodes filter out pathogens through your lymph vessels

Your immune system depends on these .04-1-inch swellings to fight all manner of pathogens. As lymph makes its way through a network of fibres in the node, white blood cells filter it, destroying any pathogens they find.

Know your enemy: Bacteria

Bacteria are the smallest and, by far, the most populous form of life on Earth. Right now, there are trillions of the single-celled creatures crawling on and in you. In fact, they constitute about four pounds of your total body weight. To the left is a look at bacteria anatomy...





Major points of the lymph node

1. Outgoing lymph vessel
The vessel that carries filtered lymph out of the lymph node

2. Valve
A structure that prevents lymph from flowing back into the lymph node

3. Vein
Passageway for blood leaving the lymph node

4. Artery
Supply of incoming blood for the lymph node

5. Reticular fibres
Divides the lymph node into individual cells

6. Capsule
The protective, shielding fibres that surround the lymph node

7. Sinus
A channel that slows the flow of lymph, giving macrophages the opportunity to destroy any detected pathogens

8. Incoming lymph vessel
A vessel that carries lymph into the lymph node

9. Lymphocyte
The T-cells, B-cells and natural killer cells that fight infection

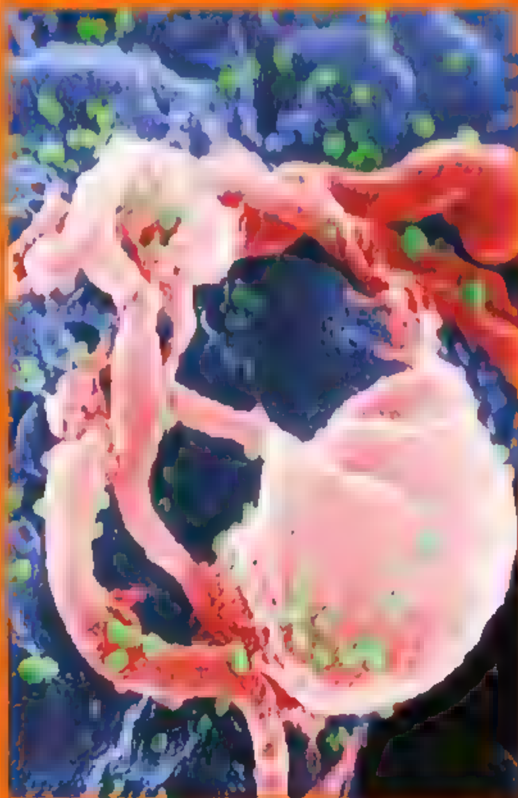
10. Germinal centre
This is the site of lymphocyte multiplication and maturation

11. Macrophage
Large white blood cells that engulf and destroy any detected pathogens

What is HIV...

...and how does it affect the immune system?

The human immunodeficiency virus (HIV) is a ret[illegible] a virus carrying ribonucleic acid, or RNA as it's known, transmitted through bodily fluids. Like other deadly viruses, HIV invades cells and multiplies rapidly inside. Specifically, HIV infects cells with CD4 molecules on their surface, which includes infect[illegible]fighting helper T-cells. HIV destroys the host cell, and the virus copies go on to infect other cells. As the virus destroys helper T-cells, it steadily weakens the immune system. If [illegible]gh T-cells are lost, the body then becomes highly susceptible to a range of different infections, a condition known as acquired immune deficiency syndrome (AIDS).



[illegible] electron micrograph of HIV-1 budding (in green) from [illegible]mphocyte. This image h[illegible] coloured to highlight [illegible]portant features. Multiple round bumps on the cell [illegible] of assembly and budd[illegible]

Bacteria vs virus

Which is which, and why does it even matter?

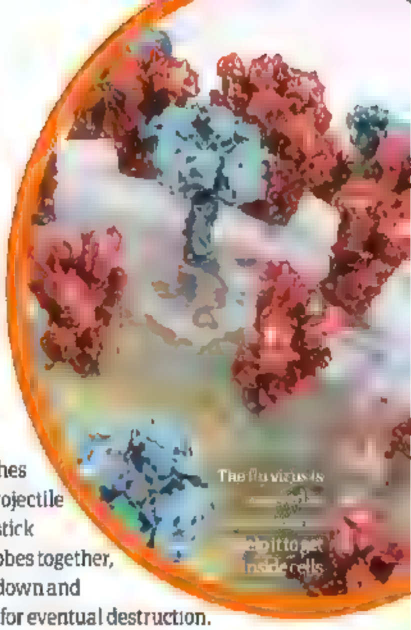
When you've got a sore throat, the cause doesn't always seem important. Some microscopic nasty is waging war with your immune system, it hurts, and you just want to feel better. But whether it's bacteria or a virus on the rampage is actually very important.

Bacteria are each made from just a single, primitive cell. Their insides are separated from the outside by a fatty membrane and a flexible coat of armour called the cell wall. Their genetic information is carried on loops of DNA, and these contain tiny factories called ribosomes, which use the genetic code to produce the molecules that the bacteria need to grow, divide and survive.

Viruses, on the other hand, are not technically alive. They carry genetic information containing the instructions to build more virus particles, but they don't have the equipment to make molecules themselves. To reproduce, they need to get inside a living cell and hijack its machinery, turning it into a virus factory.

Both bacteria and viruses can cause diseases, but knowing which is the culprit is critical to treating them effectively. Antibiotics can harm bacteria, but have no effect on viruses. Even your own immune system uses different tactics.

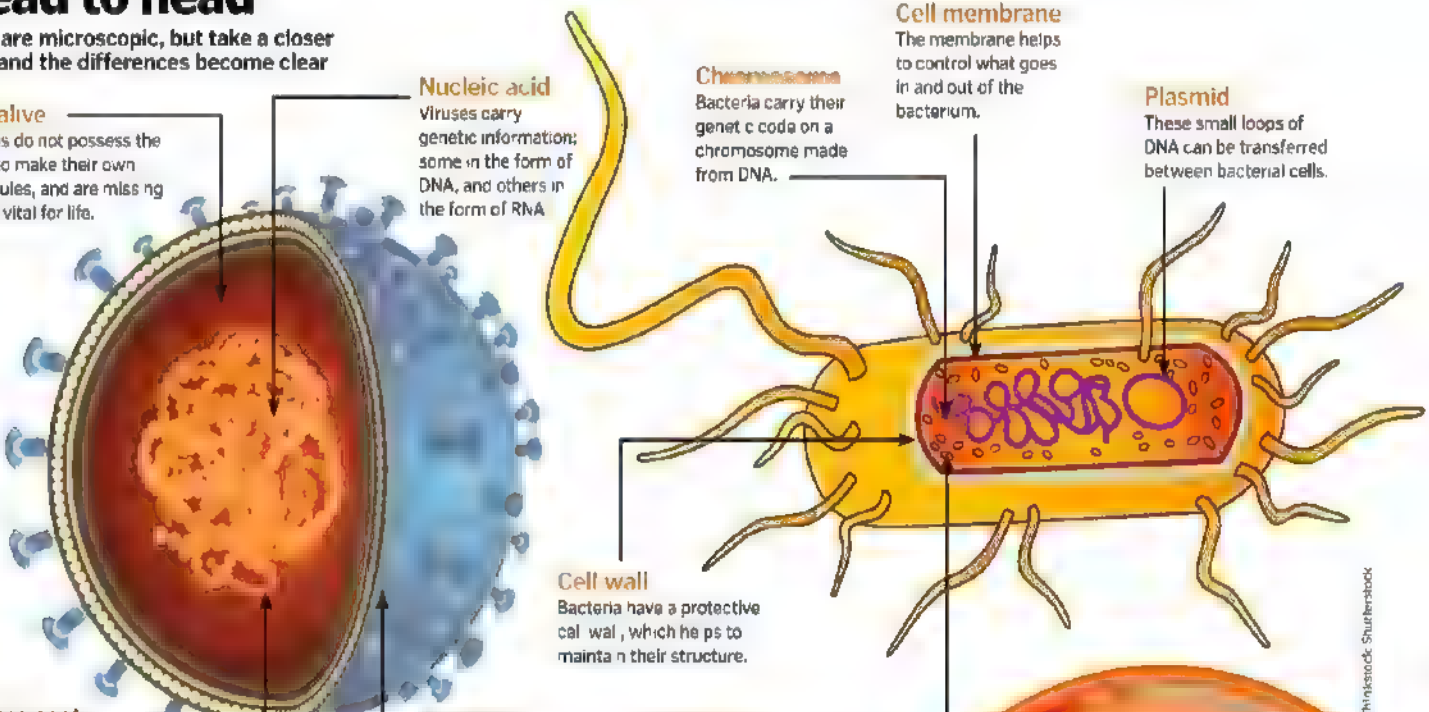
For bacteria, the immune system unleashes antibodies – projectile weapons that stick invading microbes together, slowing them down and marking them for eventual destruction. For viruses, your immune system can search for any infected cells before initiating a self-destruct sequence to dispose of anything nasty lurking inside. But some viruses are able to endure our defences, and can remain inside us indefinitely.



The flu virus is ... it to get inside cells

Head to head

Both are microscopic, but take a closer look and the differences become clear



Not alive
Viruses do not possess the tools to make their own molecules, and are missing genes vital for life.

Nucleic acid
Viruses carry genetic information; some in the form of DNA, and others in the form of RNA.

Protein coat
The virus' genetic information is stored inside a protective covering of molecules called proteins.

Envelope
Some viruses also have an outer envelope, often made from fat and protein.

Chromosome
Bacteria carry their genetic code on a chromosome made from DNA.

Cell membrane
The membrane helps to control what goes in and out of the bacterium.

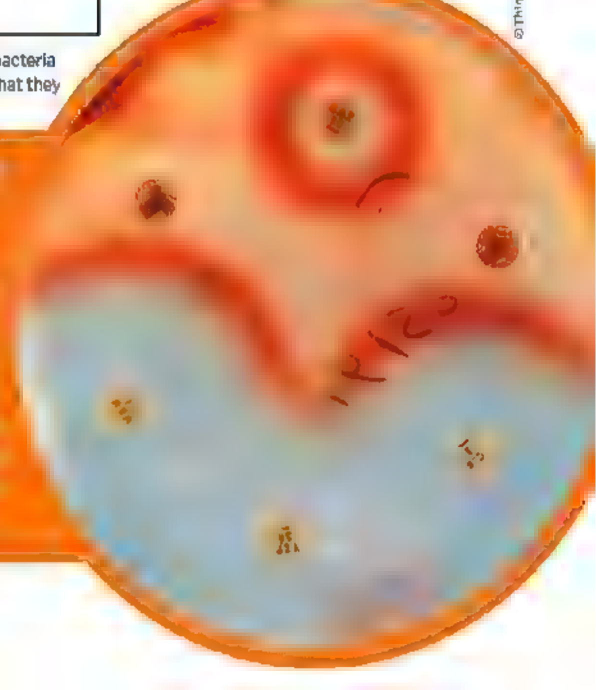
Plasmid
These small loops of DNA can be transferred between bacterial cells.

Cell wall
Bacteria have a protective cell wall, which helps to maintain their structure.

Ribosome
These structures allow bacteria to make the molecules that they need to live.

> "For viruses to reproduce, they need to get inside a living cell and hijack its machinery, turning it into a virus factory"

Antibiotic resistance



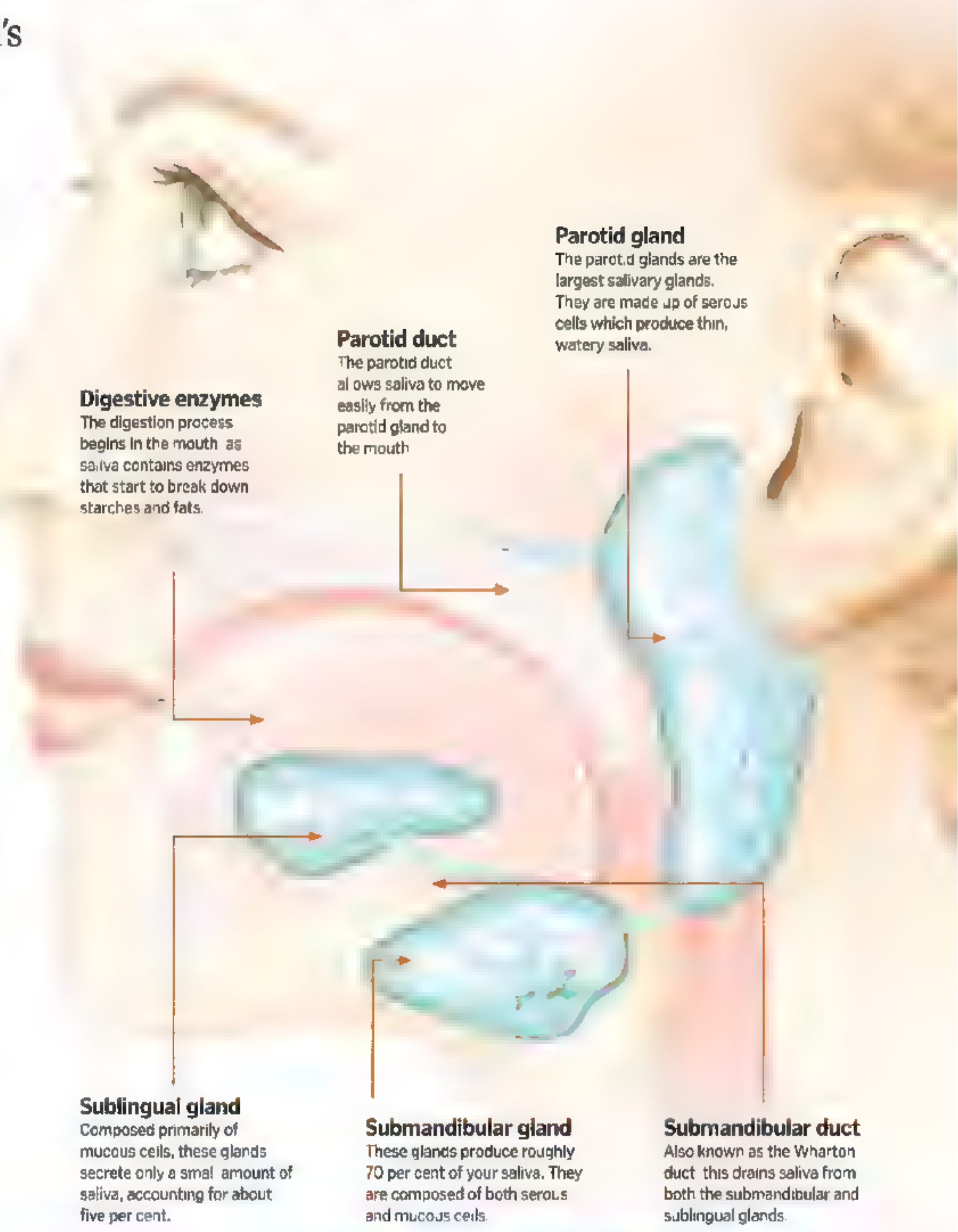
What is saliva?

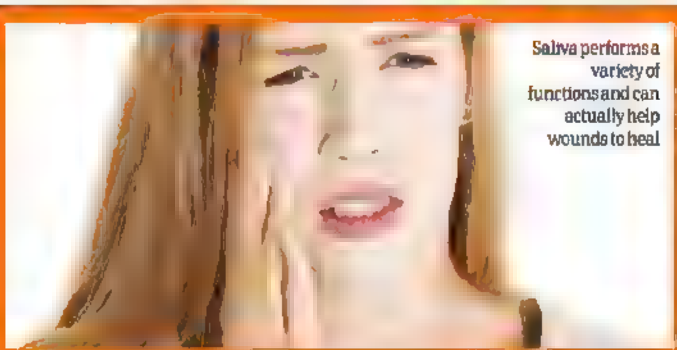
Find out this frothy liquid's vital role in maintaining human health

Humans can produce an incredible two litres (half a gallon) of saliva each day. It is made up of 99.5 per cent water, so how is it able to perform so many important functions in our mouths? The answer lies in the remaining 0.5 per cent, which contains a host of enzymes, proteins, minerals and bacterial compounds. These ingredients help to digest food and maintain oral hygiene.

As soon as food enters the mouth, saliva's enzymes start to break it down into its simpler components, while also providing lubrication to enable even the driest snack to slide easily down the throat. Saliva is also important in oral health, as it actually helps to protect the teeth from decay and it also controls bacterial levels in the mouth in order to help reduce the overall risk of infection. Without sufficient saliva, tongue and lip movements are not as smooth, which, in extreme cases, can make it very difficult to speak.

With advanced scientific techniques and research, an individual's saliva can reveal a great deal of information. New studies have shown that a saliva test can be used to find out whether a person is at risk of a heart attack, as it contains C-reactive protein (CRP). This can be an indicator of heart disease when found at elevated levels in the blood. A saliva test is much less intrusive than a blood test and gives doctors a rough estimate of the health of a patient's heart. What's more, saliva contains your entire genetic blueprint. Even tiny amounts, equivalent to less than half a teardrop, can provide a workable DNA sample that can be frozen and thawed multiple times without breaking down.





Saliva performs a variety of functions and can actually help wounds to heal

Can saliva speed up healing?

How old is your body?

You will make 2 million new red blood cells in the time it takes you to read this sentence

Your body contains 37.2 trillion cells. There are 86 billion neurons in your brain, 50 billion fat cells insulate your skin, and every cubic millimetre of your blood contains 4-6 million cells. But they don't live forever. Cells get old and damaged, and your body is constantly racing to replace them. Red blood cells only live for about three months; 50 million skin cells flake away every day; and sperm cells only last for three to five days. Read on to find out just how old you really are.

Studies of cheek lining cells in saliva have revealed that the lining of the mouth might renew as fast as every 2.7 hours.

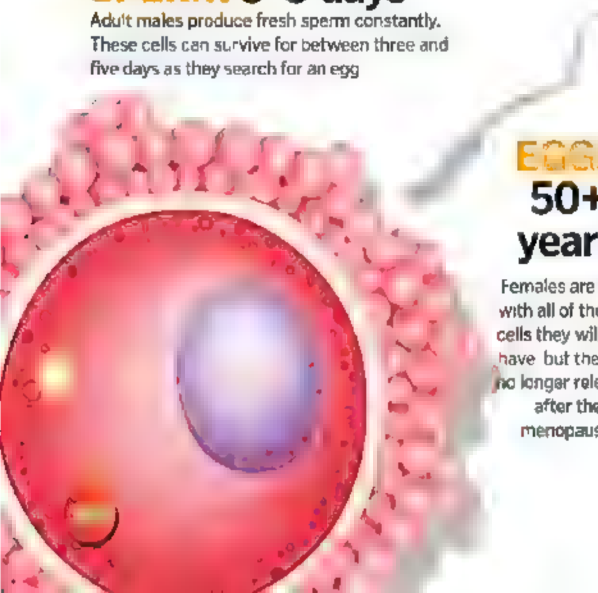
A thick layer of mucus protects the cells lining the stomach, but they are still replaced at least once a week.

Large cells called megakaryocytes make fragments called platelets, which plug leaks in blood vessels. They only last for around ten days.

There are between 18 and 23 layers of dead cells on the outside of your skin. New cells push up from below the surface every few weeks.

SPERM 3–5 days

Adult males produce fresh sperm constantly. These cells can survive for between three and five days as they search for an egg



EGGS 50+ years

Females are born with all of the egg cells they will ever have, but they are no longer released after the menopause.

LUNG LINING 8 days

The delicate lining of the lungs is just one cell thick and lasts just over a week.

CEREBRAL NEURONS 80+ years

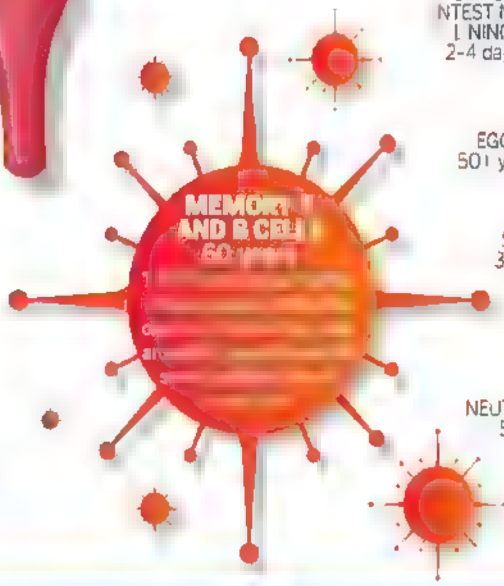
You might have heard that the whole body renews itself every seven years, but brain cells last as long as we do.

LARGE INTESTINAL LINING
3–4 days

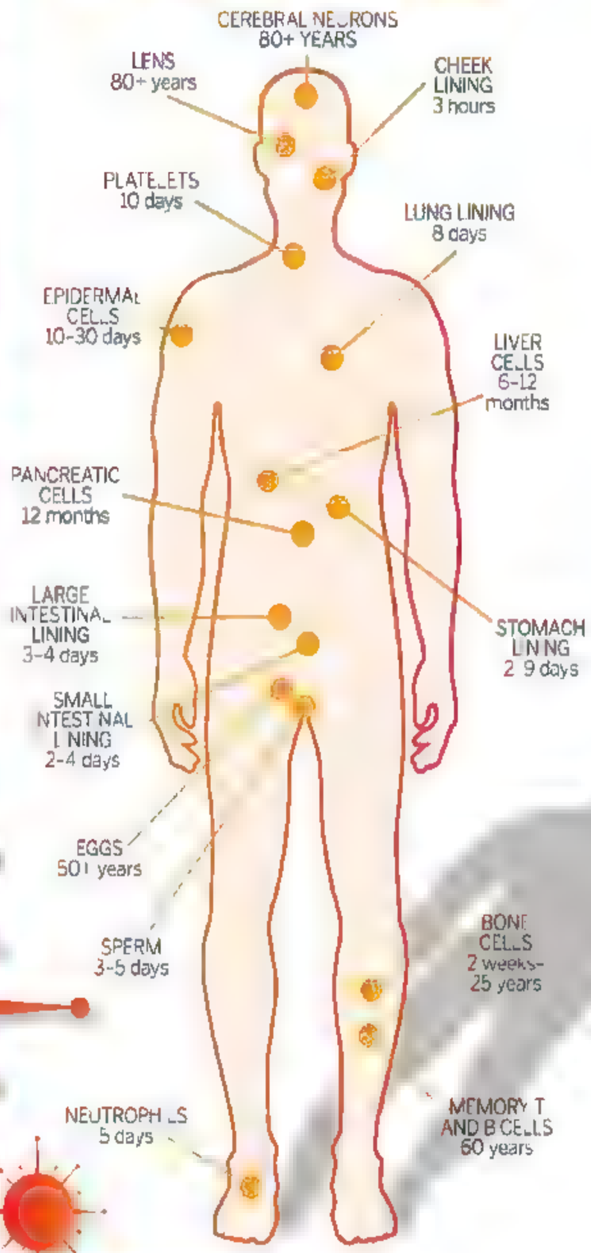
SMALL INTESTINAL LINING
2–4 days

The lining of the small intestine absorbs nutrients from digested food. It gets replaced every two to four days.

THE CELLS THAT LINE THE SMALL INTESTINE ARE SOME OF THE FASTEST-DIVIDING CELLS IN THE BODY



AN OVERVIEW TO YOUR BODY'S AGE



Beta cells in the pancreas make insulin. Their exact lifespan is still unknown, but scientists think that they live for over a year.

Liver cells normally last for 200–300 days, but they can divide rapidly if needed. Remove 75 per cent of the liver and it will grow back.

5 DAYS

White blood cells called neutrophils are first on the scene when an infection strikes. They live for less than a week.

Human pregnancy

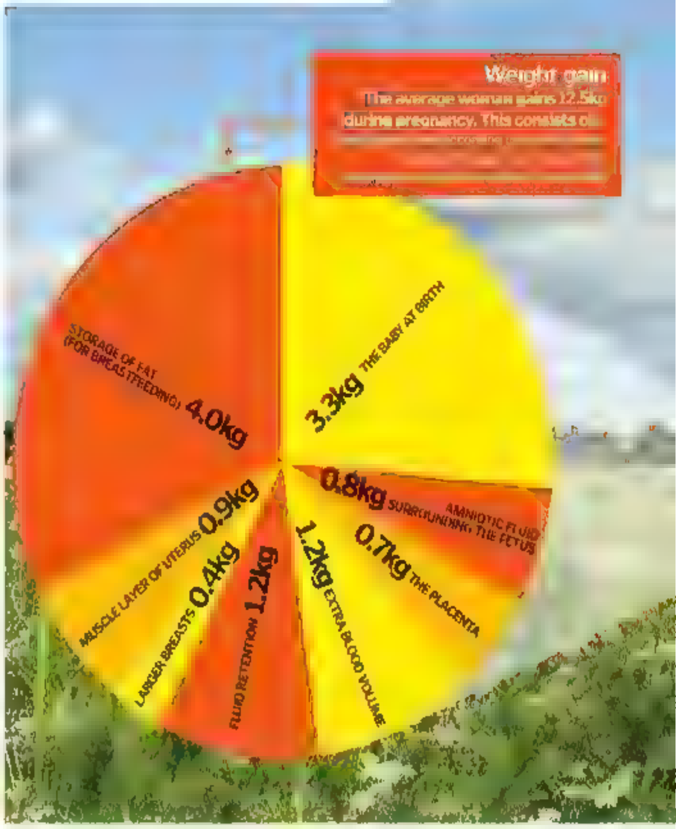
Nine months of change and growth

Pregnancy is a unique period in a woman's life that brings about physical and emotional changes. When it occurs, there is an intricate change in the balance of the oestrogen and progesterone hormones, which causes the cessation of menstruation and allows the conditions in the uterus (womb) to become suitable for the growth of the fetus. The lining of the uterus, rather than being discharged, thickens and enables the development of the baby.

At first, it is a collection of embryonic cells no bigger than a pinhead. By week four the embryo forms the brain, spinal cord and heart inside the newly fluid-filled amniotic sac. Protected by this cushion of fluid, it becomes recognisably human and enters the fetal stage by the eighth week.

Many demands are put on the mother's body and she is likely to experience sickness, tiredness, lower-back pain, heartburn, increased appetite and muscle cramps, as well as the enlargement of her breasts and stretch marks. Her blood sugar levels, heart rate and breathing also increase to cope with the growing demands of the fetus.

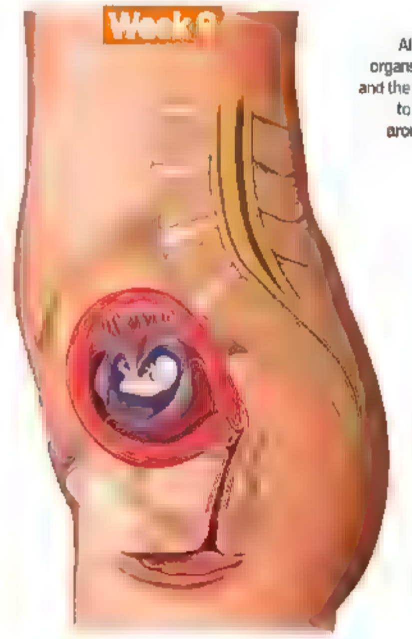
As the date of labour approaches, the mother feels sudden contractions known as Braxton-Hicks, and the neck of her uterus begins to soften and thin out. Meanwhile, the lungs of the fetus fill with surfactant. This substance enables the lungs to soften, making them able to inflate when it takes its first breath of air in the world. Finally, chemical signals from the fetus trigger the uterus to go into labour.



"At first, it is a collection of embryonic cells no bigger than a pinhead"

FIRST TRIMESTER (0-12 weeks)

This begins after the last menstrual period, when an egg is released and fertilised. It takes about nine weeks for the resulting embryo to develop into a fetus. During this period, the mother will be prone to sickness and mood swings due to hormonal changes.



Head
Face begins to look human and the brain is developing rapidly.

Heart
All the internal organs are formed and the heart is able to pump blood around its body.

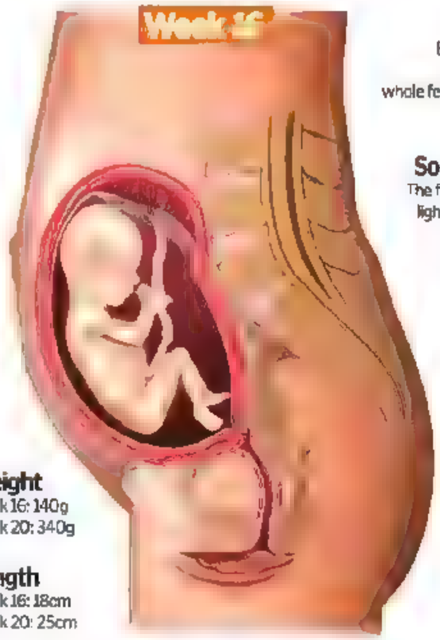
Movement
Fetus moves around to encourage muscle development.

Weight
10g

Length
5.5cm

SECOND TRIMESTER (13-27 weeks)

The fetus grows rapidly and its organs mature. By week 20 its movements can be felt. At week 24 it can suck its thumb and hiccup, and can live independently of the mother with medical support.



Hair and teeth
At 16 weeks, fine hair (lanugo) grows over the fetal body. By 20 weeks, teeth start forming in the jaw and hair grows.

Movement
By week 16 the eyes can move and the whole fetus makes vigorous movements.

Sound and light
The fetus will respond to light and is able to hear sounds such as the mother's voice.

Vernix
By 20 weeks, this white, waxy substance covers the skin, protecting it from the surrounding amniotic fluid.

Sweating
An increase in blood circulation causes mother to sweat more.

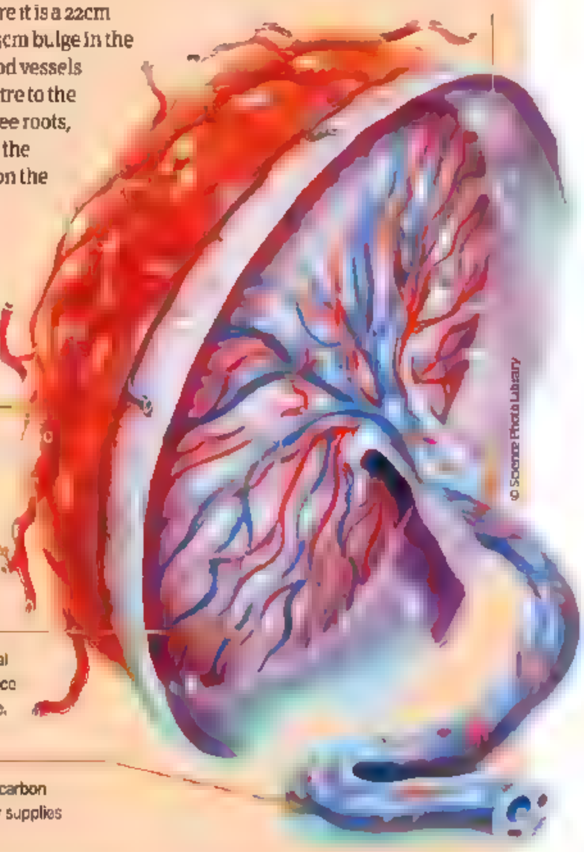
Weight
Week 16: 140g
Week 20: 340g

Length
Week 16: 18cm
Week 20: 25cm

The placenta

The placenta is an essential interface between the mother and fetus. When mature it is a 22cm diameter, flat oval shape with a 2.5cm bulge in the centre. The three intertwined blood vessels from the cord radiate from the centre to the edges of the placenta. Similar to tree roots, these villous structures penetrate the placenta and link to 15 to 20 lobes on the maternal surface.

The five major functions of the placenta as tasked with respiration, nutrition, excretion of waste products, bacterial protection and the production of vital hormones.



THIRD TRIMESTER (28-40 weeks)

Breathlessness
The increased size of the fetus by 24 weeks causes compression of rib cage and discomfort for mother.

Movement
By the 28th week, due to less room in uterus, the fetus will wriggle if it feels uncomfortable.

Hands
The fetus can move its hands to touch its umbilical cord at 24 weeks.

Position
By 28 weeks, the uterus has risen to a position between the navel and the breastbone.

Weight
Week 24: 650g
Week 28: 1,250g

Length
Week 24: 34cm
Week 28: 38cm

Head
The head can move at 28 weeks and the eyes can open and see

Now almost at full term, the fetus can recognise and respond to sounds and changes in light. Fat begins to be stored under the skin and the lungs are the very last organs to mature.

Weight
1,500g

Length
41cm

"The three intertwined blood vessels radiate from the centre to the edges of the placenta"

Under pressure
Pressure on the diaphragm and other organs causes indigestion and heartburn in the mother. She will find it difficult to eat a lot.

Position
Head positions itself downwards, in preparation for labour.

Sleep patterns
Fetus will sleep and wake in 20-minute cycles.

Hormones

How the human endocrine system develops and controls the human body

The glands in the endocrine system use chemicals called hormones to communicate with and control the cells and organs in our bodies. They are ductless glands that secrete different types of hormones directly into the bloodstream which then target specific organs.

The target organs contain hormone receptors that respond to the chemical instructions supplied by the hormone. There are 50 different types of hormone in the body and they all consist of three basic types: peptides, amines and steroids.

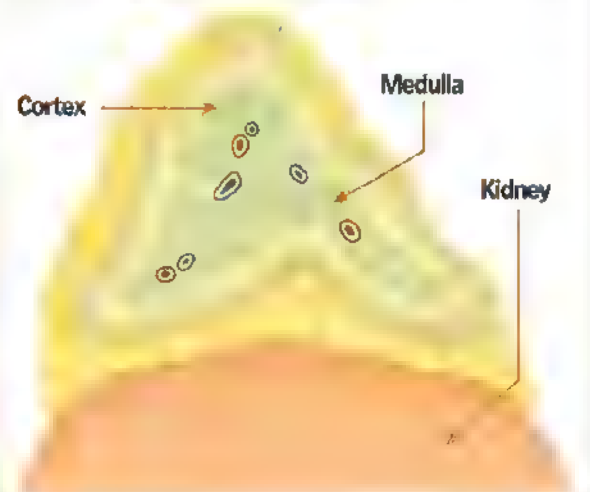
Steroids include the testosterone hormone. This is not only secreted by the cortex of the adrenal gland, but also from the male and female reproductive organs and by the placenta in pregnant women. The majority of hormones are called peptides that consist of short chains of amino acids. They are secreted by the pituitary and parathyroid glands. Amine hormones are secreted by the thyroid and adrenal medulla and are related to initiating the fight or flight response in our bodies.

The changes that are caused by the endocrine system act more slowly than the nervous system as they regulate growth, moods, metabolism, reproductive processes and a relatively constant stable internal environment for the body (homeostasis). The pituitary, thyroid and adrenal glands then all combine to form the major elements of the body's endocrine system along with various other elements such as the male testes, the female ovaries and the pancreas.

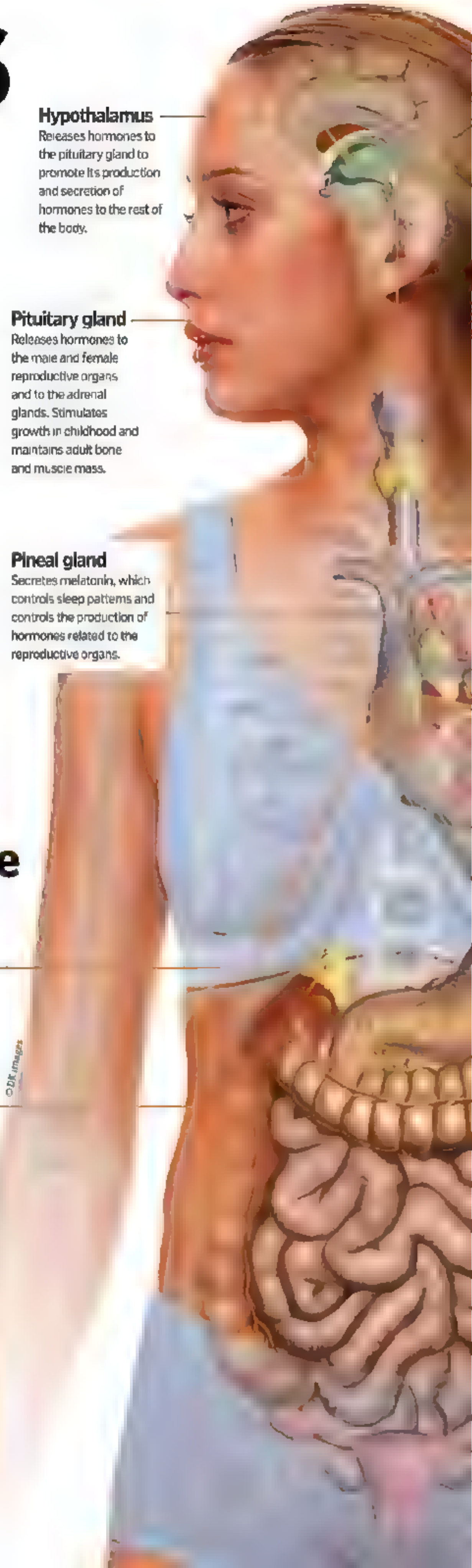
"Amine hormones are secreted by the thyroid and adrenal medulla"

Adrenal gland

We have two adrenal glands that are positioned on top of both kidneys. The triangular-shaped glands each consist of a two-centimetre thick outer cortex that produces steroid hormones, which include testosterone, cortisol and aldosterone. The ellipsoid shaped, inner part of the gland is known as the medulla, which produces noradrenaline and adrenaline. These hormones increase the heart rate, and the body's levels of oxygen and glucose while reducing non-essential body functions. The adrenal gland is known as the 'fight or flight' gland as it controls how we respond to stressful situations, and prepares the body for the demands of either fighting or running away as fast as you can. Prolonged stress over-loads this gland and causes illness.



The endocrine system



Thymus
Is part of the immune system. It produces thymosins that control the behaviour of white blood T-cells.

Adrenal glands
Controls the burning of protein and fat, and regulates blood pressure. The medulla secretes adrenaline to stimulate the fight or flight response.

Male testes
These two glands produce testosterone that is responsible for sperm production, muscle and bone mass and sex drive.

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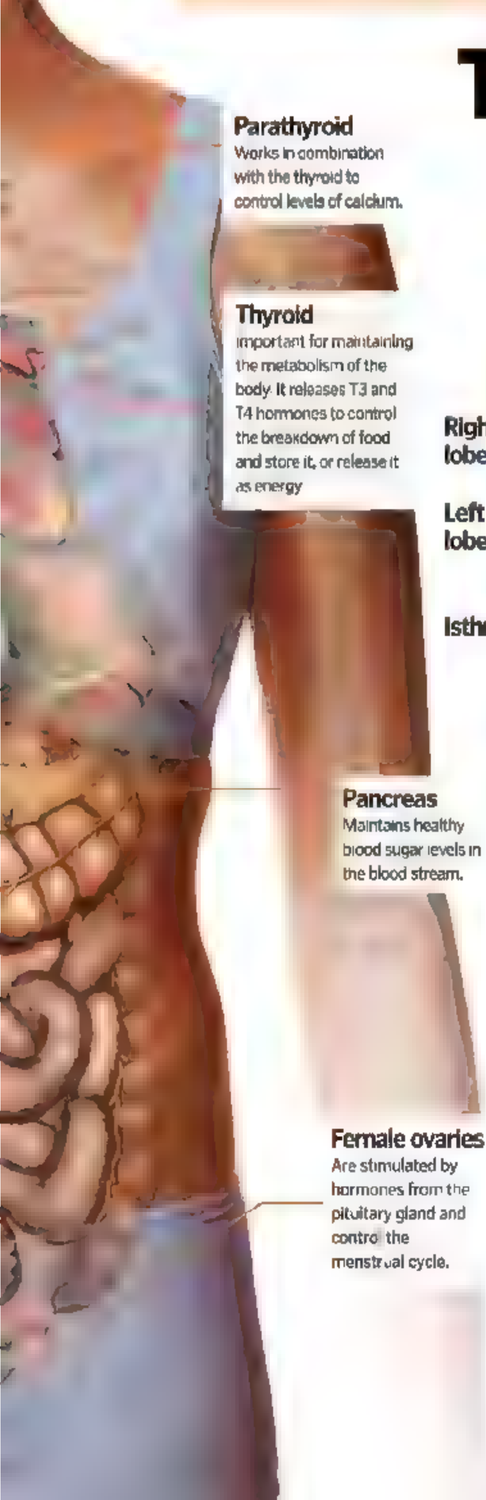
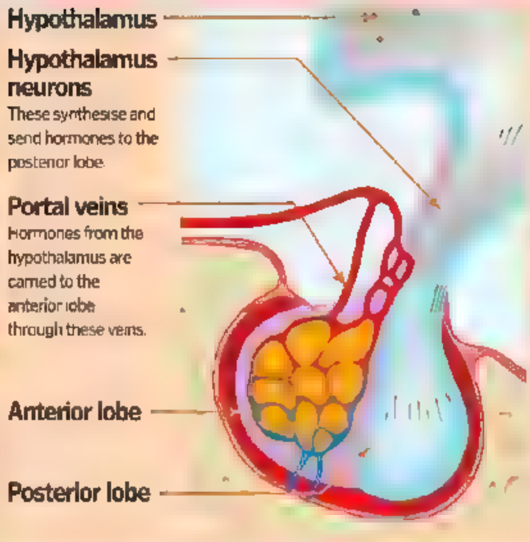


Pituitary gland

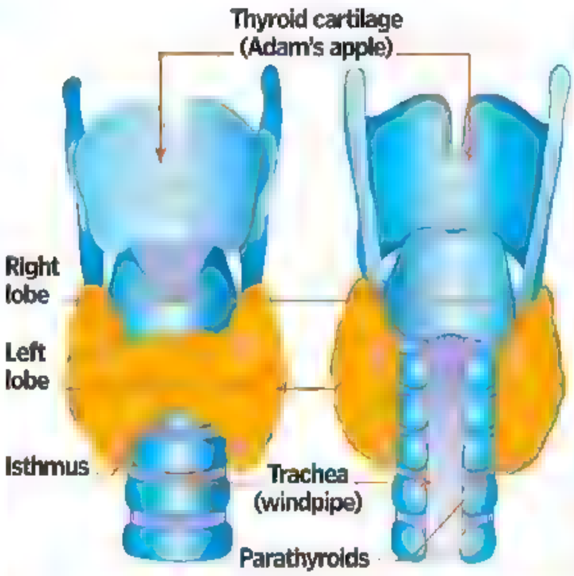


The pea-sized pituitary gland is a major endocrine gland that works under the control of the hypothalamus. The two organs inside an individuals brain work in concert and mediate feedback loops in the endocrine system to maintain control and stability within the body.

The pituitary gland features an anterior (front) lobe and a posterior (rear) lobe. The anterior lobe secretes growth hormones that stimulate the development of the muscles and bones, it also stimulates the development of ovarian follicles in the female ovary. In males, it is this that actually stimulates the production of sperm cells. The posterior lobe stores vasopressin and oxytocin that is supplied by the hypothalamus. Vasopressin allows the retention of water in the kidneys and suppresses the need to excrete urine. It also raises blood pressure by contracting the blood vessels in the heart and lungs.

Oxytocin influences the dilation of the cervix before giving birth and the contraction of the uterus after birth. The lactation of the mammary glands are stimulated by oxytocin when mothers begin to breastfeed.

Thyroid and parathyroids



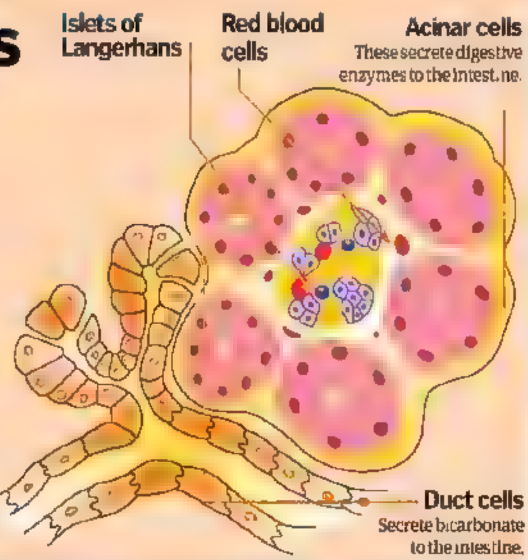
The two lobes of the thyroid sit on each side of the windpipe and are linked together by the isthmus that runs in front of the windpipe. It stimulates the amount of body oxygen and energy consumption, thereby keeping the metabolic rate of the body at the current levels to keep you healthy and active.

The hypothalamus and the anterior pituitary gland are in overall control of the thyroid and they respond to changes in the body by either suppressing or increasing thyroid-stimulating hormones. Overactive thyroids cause excessive sweating, weight loss and sensitivity to heat, whereas underactive thyroids cause sensitivity to hot and cold, baldness and weight gain. The thyroid can swell during puberty and pregnancy or due to viral infections or lack of iodine in a person's diet.

The four small parathyroids regulate the calcium levels in the body; it releases hormones when calcium levels are low. If the level of calcium is too high the thyroid releases calcitonin to reduce it. Therefore, the thyroid and parathyroids work in tandem.

Pancreatic cells

The pancreas is positioned in the abdominal cavity above the small intestine. Consisting of two types of cell, the exocrine cells do not secrete their output into the bloodstream but the endocrine cells do. The endocrine cells are contained in clusters called the islets of Langerhans. They number approximately 1 million cells and are only one or two per cent of the total number of cells in the pancreas. There are four types of endocrine cells in the pancreas. The beta cells secrete insulin and the alpha cells secrete glucagon, both of which stimulate the production of blood sugar (glucose) in the body. If the Beta cells die or are destroyed it causes type 1 diabetes, which is fatal unless treated with insulin injections. The other two cells are the gamma and delta cells. The former reduces appetite



GENETICS

From inheritance to genetic diseases, what secrets are hidden in our genes and how do they determine who we are?

How is our genetic code stored?

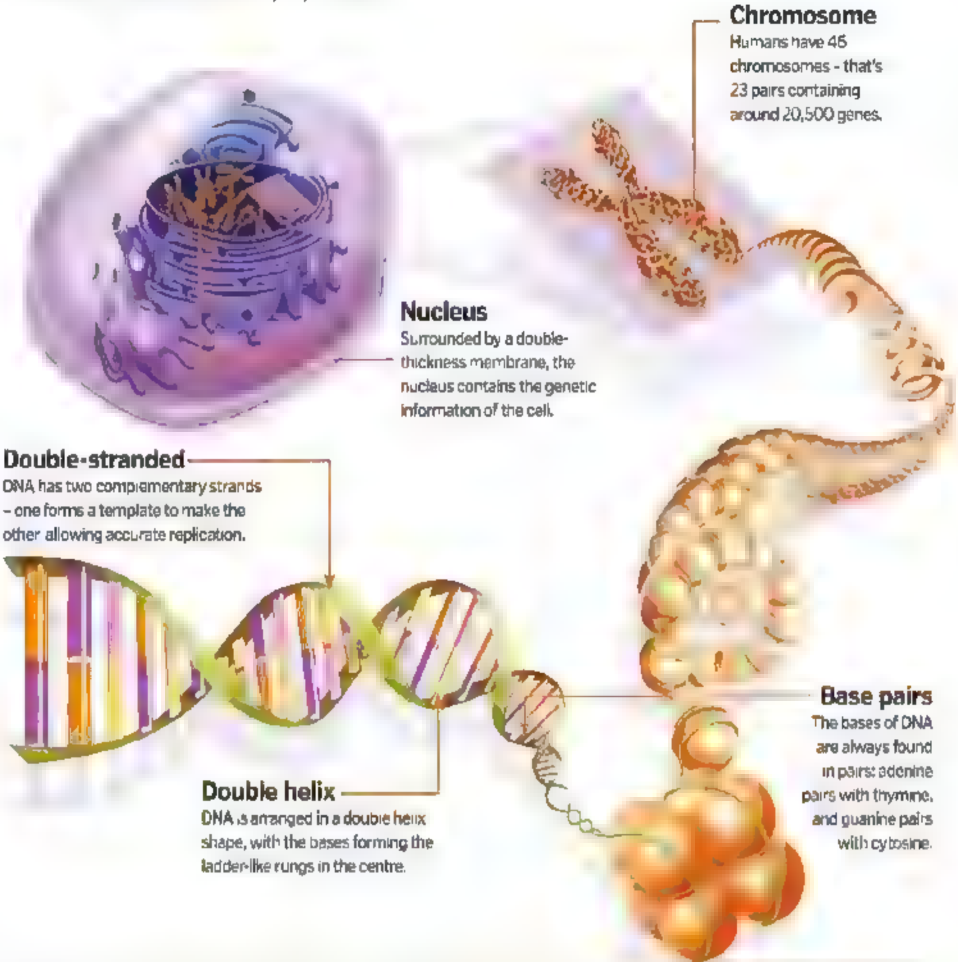
Genetic information is coded into DNA using just four nucleobases: A, C, G and T

Genes define who we are. They are the basic unit of heredity, each containing a coded set of instructions to make a protein. Humans have an estimated 20,500 genes, varying in length from a few hundred to more than 2 million base pairs. They affect all aspects of our physiology, providing the code that determines our physical appearance, the biochemical reactions that occur inside our cells and even, many argue, our personalities.

Every individual has two copies of every gene – one inherited from each parent. Within the population there are several alleles of each gene – that is, different forms of the same code, with a number of minor alterations in the sequence. These alleles perform the same underlying function, but it is the subtle differences that make each of us unique.

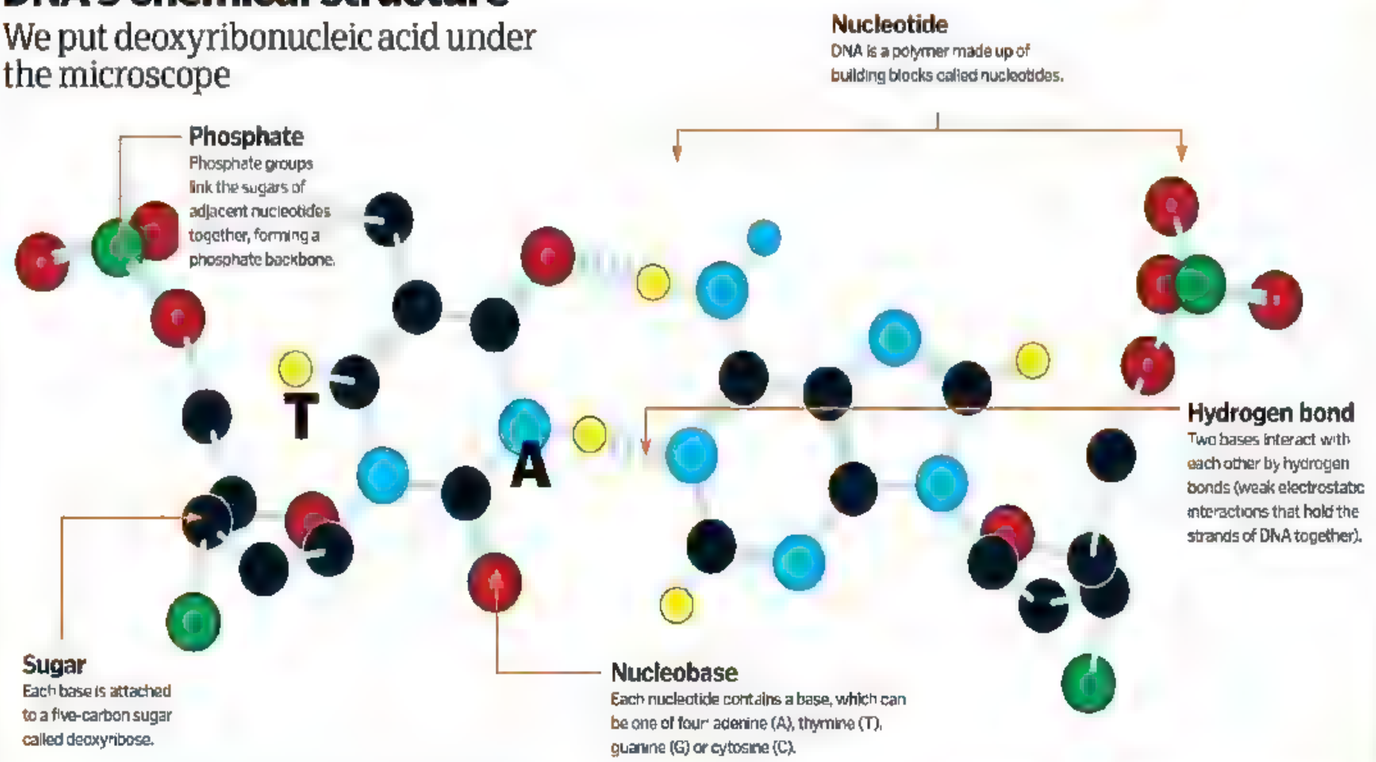
Inside each of our cells (except red blood cells) is a nucleus, the core which contains our genetic information: deoxyribonucleic acid (DNA). DNA is a four-letter code made up of bases: adenine (A), guanine (G), cytosine (C) and thymine (T). As molecular biologist Francis Crick once put it, "DNA makes RNA, RNA makes protein and proteins make us." Our genes are stored in groups of several thousand on 23 pairs of chromosomes in the nucleus, so when a cell needs to use one particular gene, it makes a temporary copy of the sequence in the form of ribonucleic acid (RNA). This copy contains all of the information required to make a protein – the building blocks of the human body.

The Human Genome Project aimed to map the entire human genome; this map is effectively a blueprint for making a human. Using the information hidden within our genetic code,



DNA's chemical structure

We put deoxyribonucleic acid under the microscope



scientists have been able to identify genes that contribute to various diseases. By logging common genetic variation in the human population, researchers have actually been able to identify over 1,800 disease-associated genes, affecting illnesses ranging from breast cancer to Alzheimer's. The underlying genetic influences that affect complex diseases such as heart disease are still not yet fully understood, but having the genome available to study is making the task of identifying the genetic risk factors much easier.

Interestingly, the Human Genome Project discovered we have far fewer genes than first predicted; in fact, only two per cent of our genome codes for proteins. The remainder of the DNA is known as 'non-coding' and serves other functions. In many human genes are non-coding regions called introns, and between genes there is intergenic DNA. One proposed function is that these sequences act as a buffer to protect the important genetic information from mutation. Other non-coding DNA acts as switches, which helps the cell to turn genes on and off at the right times.

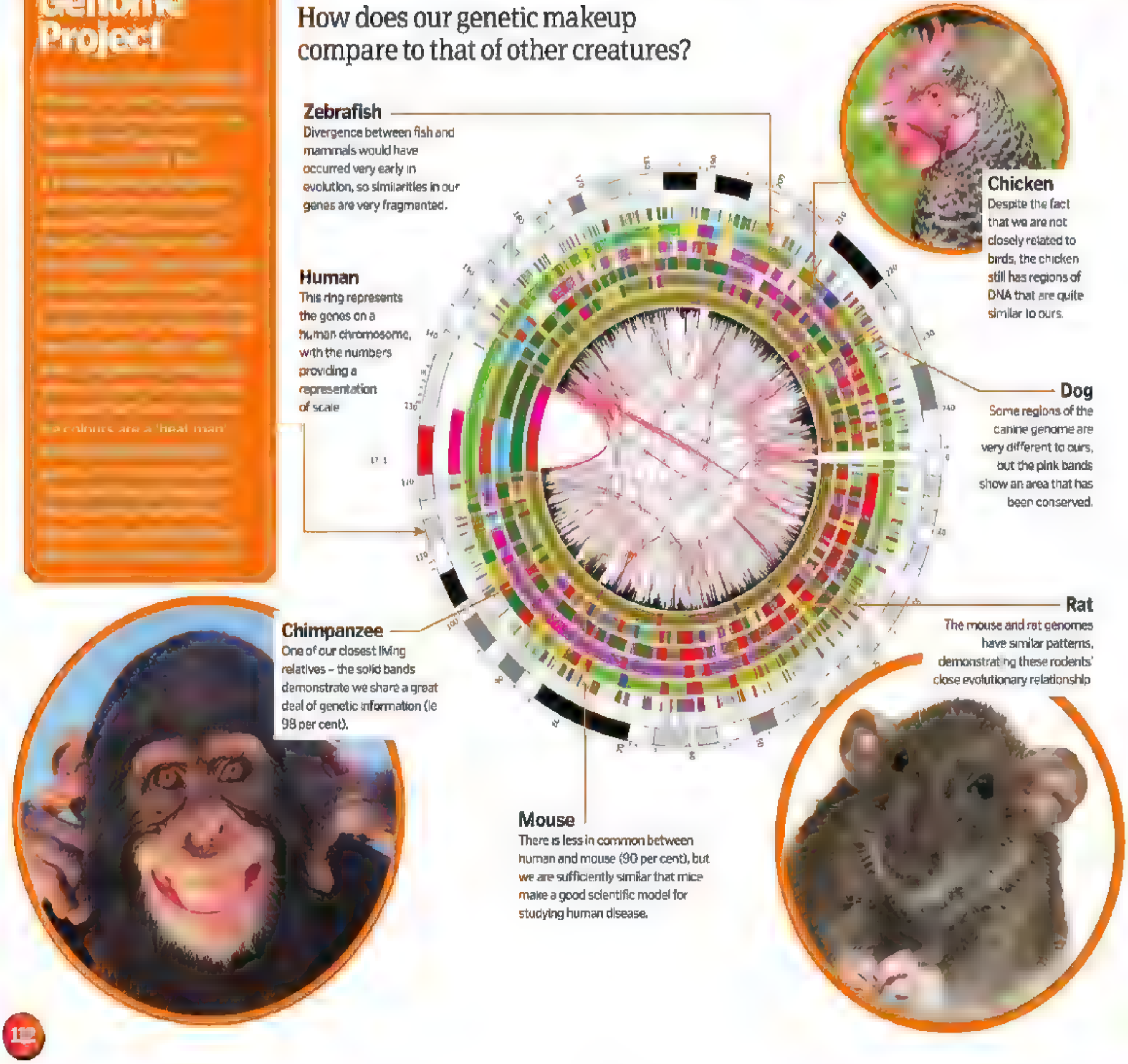
Genetic mutations are the source of variation in all organisms. Most genetic mutation occurs as the DNA is being copied, when cells prepare to divide. The molecular machinery responsible for duplicating DNA is prone to errors, and often makes mistakes, resulting in changes to the DNA sequence. These can be as simple as accidentally substituting one base for another (eg A for G), or can be much larger errors, like adding or deleting bases. Cells have repair machinery to correct errors as they occur, and even to kill the cell if it makes a big mistake, but despite this some errors still slip through.

Throughout your life you will acquire many cell mutations. Many of these are harmless, either occurring in non-coding regions of DNA, or changing the gene so nominally that the protein is virtually unaffected. However, some mutations do lead to disease. If mutations are introduced into the sperm and egg cells they can be passed on to the next generation. However, not all mutations are bad, and this process of randomly introduced changes in the DNA sequence provides the biological underpinning that supports Darwin's theory of evolution. This is most easily observed in animals. Take, for example, the peppered moth. Before the Industrial Revolution

The Human Genome Project

Mapping the human genome

How does our genetic makeup compare to that of other creatures?



the majority of these moths had white wings, enabling them to hide against light-coloured trees and lichens. A minority had a mutant gene, which gave them black wings; this made them an easy target for predators. When factories began to cover the trees in soot, the light-coloured moths struggled to hide themselves against the darker environment, so black moths flourished. They survived much longer, enabling them to pass on their mutation to their offspring and altering the gene pool.

It is easy to see how a genetic change like the one that occurred in the peppered moth could give an advantage to a species, but what about genetic diseases? Even these can work to our advantage. A good example is sickle cell anaemia – a genetic disorder that's quite common in the African population. A single nucleotide mutation causes haemoglobin, the protein involved in binding oxygen in red blood cells, to misfold. Instead of forming its proper shape, the haemoglobin clumps together, causing red blood cells to deform. They then have trouble fitting through narrow capillaries and often become damaged or destroyed. However, this genetic mutation persists in the population because it has a protective effect against malaria. The malaria parasite spends part of its life cycle inside red blood cells and, when sickle cells rupture, it prevents the parasite from reproducing. Individuals with one copy of the sickle cell gene and one copy of the healthy haemoglobin gene have few symptoms of sickle cell anaemia, but are protected from malaria too, allowing them to pass the gene on to their children.

Genetics is a complex and rapidly evolving field and more information about the function of DNA is being discovered all the time. It is now known that environmental influences can alter the way that DNA is packaged in the cell, restricting access to some genes and altering protein expression patterns. Known as epigenetics, these modifications do not actually alter the underlying DNA sequence, but regulate how it is accessed and used by the cell. Epigenetic changes can be passed on from one cell to its offspring, and provide an additional mechanism by which genetic information can be modified across generations.

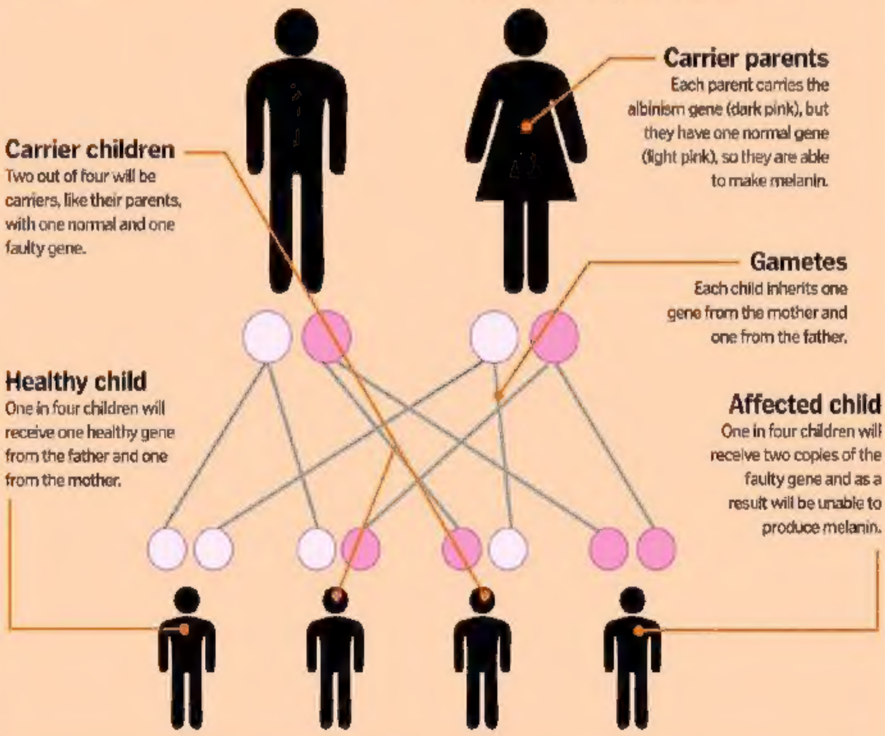
> "Before the Industrial Revolution, most peppered moths had white wings"

Using genetics to convict criminals

Forensic scientists can use traces of DNA to identify individuals involved in criminal activity. Only about 0.1 per cent of the genome differs between individuals, so rather than sequencing the entire genome, scientists take 13 DNA regions that are known to vary between different people in order to create a 'DNA fingerprint'. In each of these regions there are two to 13 nucleotides in a repeating pattern hundreds of bases long – the length varies between individuals. Small pieces of DNA – referred to as probes – are used to identify these repeats and the length of each is determined by a technique called polymerase chain reaction (PCR). The odds that two people will have exactly the same 13-region profile is thought to be one in a billion or even less, so if all 13 regions are found to be a match then scientists can be fairly confident that they can tie a person to a crime scene.

Why do we look like our parents?

It's a common misconception that we inherit entire features from our parents – eg "You have your father's eyes." Actually inheritance is much more complicated – several genes work together to create traits in physical appearance; even eye colour isn't just down to one gene that codes for 'blue', 'brown' or 'green', etc. The combinations of genes from both of our parents create a mixture of their traits. However, there are some examples of single genes that do dictate an obvious physical characteristic all on their own. These are known as Mendelian traits, after the scientist Gregor Mendel who studied genetic inheritance in peas in the 1800s. One such trait is albinism – the absence of pigment in the skin, hair and eyes due to a defect in the protein that makes melanin.

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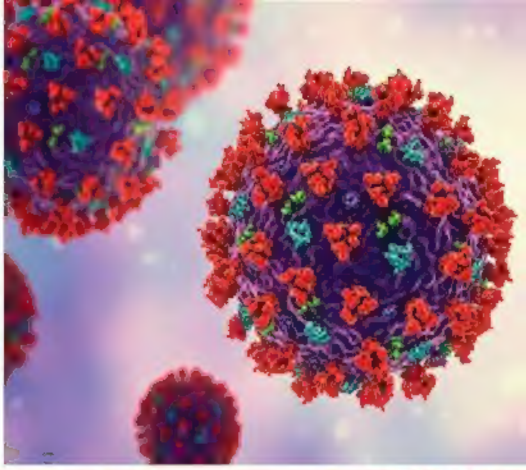

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